SPONTANEOUS INTERPERSONAL COORDINATION

IN CHILDREN WITH AUTISM

A THESIS

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL OF THE

UNIVERSITY OF MINNESOTA

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

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May, 2015

ACKNOWLEDGEMENTS

First and foremost, I want to thank God for the strength, courage, and faith to complete this educational goal, without him I am nothing. I ask for continued guidance and blessings as I now take what I have learned and share it with my future students.

I cannot thank my family enough for all the love, support and encouragement. There were many times I really needed you to encourage and motivate me as I was starting to think I would never be able to accomplish this task. So, best light some candles for effect, bake some brownies, break out the pretzels and sardines, and be ready with the introductions.

Great appreciation and gratitude are extended to Dr. Michael Wade, my academic advisor for the past 5 years. I could not have completed my journey to obtaining my PhD. in Kinesiology without you.

I wish to extend my gratefulness to Dr. Thomas Stoffregen, who served as the chairman on my committee and as a reader of my dissertation. I have learned a great deal from you and though getting up and presenting in your classes was one of the most intimidating experiences of my time at the University of Minnesota, next to my defense, I know it has better prepared me for future classes in which I will be the instructor.

I could not have completed the statistical portion of this dissertation without the assistance of Dr. Robert del Mas and though I have said thank you many times, I do not think I will ever be able to say it enough. You are a statistical genius and I know I would not have completed my analysis without your assistance.

My appreciation is extended to Dr. Richard Rodgerson for not only serving on my committee, but taking the time to advise me on various literary aspects of my research.

I would also like to thank the schools, parents and participants for taking part in my research, I really could not have done it without your assistance and participation.

Chad, there are not enough words to express my gratitude for everything you have done. I know this has been a long stressful journey with both its ups and downs, and I could not have done it without all your love, support, encouragement, and patience. We can finally move forward with all the plans and dreams we have for our future. I love you so much.

ABSTRACT

This study investigated the ability of pairs of children with Autism (ASD) and typically developing (TD) children to spontaneously coordinate their rocking movements while exposed to visual and auditory stimuli. The central research question sought to determine if children with ASD could coordinate their rocking movements in situations where social interaction was required. Pairs of TD children and pairs of children with ASD performed rocking tasks, while sitting side-by-side. Each pair completed four experimental conditions of three trials each, during which they were instructed to rock while either directing their gaze forward (FF) or directly (DF) at their partner. Participants were also paced with a metronome in two of the four conditions (one FF and one DF). Results revealed a general consistency for rocking frequency between both groups, although TD children demonstrated a more consistent and coordinated syncing ability. Contrary to the hypothesis, children with ASD synced better in DF no paced conditions than in the FF paced condition. However, further studies need to be conducted to determine if all auditory stimuli or only certain sounds (i.e., music vs tick of a metronome) has an effect on the ability of children with ASD to coordinate rocking movements with a partner.

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CHAPTER 1

IDENTIFYING THE PROBLEM

Introduction

Social interactions are a part of our daily lives whether conversing with close friends, crossing the street against a crowd of people traveling in the opposite direction, or making eye contact and nodding to a random stranger to acknowledge them when holding a door open. Social interactions not only allow us to detect and interpret other people's thoughts, intentions, desires and beliefs, but also to engage with others in complex social groups and intimate relationships (Baron-Cohen, Ring, Wheelwright, Bullmore, Brammer, Simmons & Williams, 1999). Engaging others in social interactions also allows us observe and read their behavior (i.e. both mental and physical) in order to predict how they might feel, think or act (Baron-Cohen, et al., 1999). Given that social interactions have been a part of our lives since we were born it would seem that interacting with others should be effortless. However, while social interaction and coordination may not be a problem for most people, the same is not true for individuals whose perceptions of social normalcy may be skewed by a disability. Children with autism (ASD) do not perceive their environment or others in the same way as typically developing (TD) children (Crocker, Ekland & Kowalski, 2000; O'Neill & Jones, 1997). Children with ASD do not behave or interact in ways deemed to be socially acceptable; they have to be taught how to perceive other people's body language, how to respect and allow others' personal space, how to hold a conversation, and how to maintain eye contact while communicating (Bass & Mulick, 2007; Joseph, Tager-Flusberg & Lord, 2002; Macintosh & Dissanayake, 2006; Scattone, 2007; Stahmer & Schreibman, 1992).

When studying socially acceptable behavior and coordinated movement children with ASD are compared to TD children. Previous research (Grossberg & Seidman, 2006; Marsh, Isenhower, Richardson, Helt, Verbalis, Schmidt & Fein, 2013; Schmidt & Richardson, 2008) has shown TD children as generally performing physical tasks better, which leads to the central research question of the present study. Can pairs of ASD children show levels of interpersonal coordination (rocking together in chairs) compared to pairs of typically developing children?

Autism Spectrum Disorder (ASD) is defined as a variety of neurodevelopmental conditions categorized into three groups; language, socialization, and behavior to enable clear classification for diagnosis (DSM-IV-TR, 2000; DSM-V-TR, 2014). The shared limitations of the three groups include mild to severe disturbances in social settings, limited social behaviors and tendencies to engage in unusual socially unacceptable behavioral. While exact mannerism displayed by an individual are case specific, the common identifying characteristics of ASD may include, but are not limited to, unusual verbalizations, lack of eye contact, hand flapping, finger clicking, and rocking. These characteristics are most often displayed when the individual with ASD is placed in a situation where there is high anxiety and/or there is an abrupt change in routine (Chairman, Jones, Pickles, Simmonoff, Baird & Happe', 2010; Colle, Baron-Cohen, & Hill, 2007; Klin, Saulier, Sparrow, Cicchetti, Volkmann & Lord, 2007).

Previous research suggests that impairments in motor function may have an influence on core characteristics of ASD (Henderson & Sugden, 1992; Hughes, 1996; Leary & Hill, 1996). While movement deficiencies and or motor clumsiness (Hughes, 1996) is not considered "established diagnostic criteria for Autism" (Blancher & Christensen, 2011, p. 182) there is evidence that motor limitations and deficiencies in social behavior are linked. Studies supporting this connection between movement and social behavior include Damasio & Mauer (1978) and Vilensky, Damasio & Mauer (1981). Their findings report that individuals with ASD have awkward gait and abnormal upper body posturing when walking; individuals with ASD walk at a slower pace with a decreased stride length. Movement limitations alone can lead to social awkwardness, but the inability to coordinate physically with others can lead to social isolation. Baranek's (2002) study examined the senses and how they are affected by motor function, the study concluded that children with ASD demonstrate odd social behavior in their sensory motor functioning. These behaviors included limited visual attention and tracking, excessive mouthing of objects, and a strong dislike for being touched by others in social situations. Hughes & Russell (1993) suggested that children with ASD, especially those who are higher functioning, have a problem with executive functioning. Rinehart, Bradshaw, Brereton & Tonge state that individuals with ASD as having "failure to predict movement or having impaired visual control of movement (2001, p.81) hinting at the possibility that perhaps the inability to physically perform and behave in a socially appropriate manner are one in the same.

Statement of the Problem

The present study investigated the impact of visual contact (i.e., looking ahead or looking at your partner) and auditory pacing comparing pairs of TD children and children with ASD and their ability to spontaneously coordinate interpersonal movement. From the central research statement above the following hypotheses were developed.

Hypotheses

1. Children with ASD will exhibit lower levels of synchronized rocking when compared to TD children.
2. Pairs of ASD children will yield higher levels of coordinated rocking when looking ahead (FF) then when maintaining eye contact with each other (DF).
3. Children with ASD will exhibit higher synchronization rates in the pacing condition (metronome is present) FFWM and DFWM compared to conditions with no metronome FFNM and DFNM.

Significance of the Study

The present study not only expands on earlier studies, but also provides comparison data and insight on the ability of TD children and children diagnosed with ASD to synchronize their rocking patterns. Previous research has concluded that children with ASD display low levels of interpersonal coordination (Bass & Mulick, 2007; Macintosh & Dissanayake, 2006; Scattone, 2007). This study's focus was on the manipulation of both visual and auditory stimuli during rocking trials, looking for a possible link between the level of coordination in movement and the social behavior in children with ASD (Klin et al., 2007; Miles Takanhashi, Bagby, Sahota, Vaslow, Wang, Hillman & Farmer, 2005; O'Neill & Jones, 1997; Scattone, 2007).

Study Assumptions

The present study was based on the following assumptions:

1. Participants would demonstrate the ability to rock back and forth, putting forth their best efforts during the study.
2. Fatigue would minimally affect the rocking performances of the participants as a trial length was only 2 minutes, and rest intervals were given between all conditions and trials.
3. Information obtained from the participants was accurate and reliable.

Definition of Terms

The following definitions of terms used in this study are as follows:

Chi-Squared- A non-parametric statistical technique used to determine the significance of differences between frequency counts on nominal data that have been arranged into categories. There is no variability within categories and all subjects are of equal value. The classifications of subjects must be mutually exclusive meaning a subject may only classified into one category. (Vincent, 1999)

Participant 1B- Defined as the chair/position of a participant pair during a testing session; this participant was assigned transmitter port 1 and chair B. While participants would change testing sessions, the chair and position stayed the same both in the room setup and on the spreadsheet for trials during the conditions of the testing sessions.

Participant 3A- Defined as the chair/position of a participant pair during a testing session; this participant was assigned transmitter port 3 and chair A. While participants would change testing sessions, the chair and position stayed the same both in the room setup and on the spreadsheet for trials during the conditions of the testing sessions.

Radians- An International Systems of Measure (SI) unit of a single plane angle, also a measure of a central angle subtending as an arc equal in length to the radius. 1 radian is equal to 57.2958 degrees (Webster, 2014). The angle that represents a length of one radius on a unit circle. Circumference = $2\pi r$.

Synchronization- Defined by Webster (2014) as causing to go on, move, operate, or work, etc., at the same rate and exactly together. This study accepted any form of partner rocking synchronization (i.e., in-phase or anti-phase) as “syncing up” or moving together.

Traveling- Defined as the movement or drifting of the rocking chairs, used by participant groups, beyond the standard forward-backward motion of the rocking chair (i.e., movement into another plane, or moving farther forward or backward than what is considered the standard rocking area for the chair).

CHAPTER II

LITERATURE REVIEW

Introduction

Have you ever watched total strangers dance? Not the type of dance that provides music or takes place in a ballroom venue; the kind of dance that can occur at any place and anytime. More often than not this dance is a chance meeting that will involve two totally random individuals traveling in opposite directions on the same path. While awkward, unintentional, unplanned, and not choreographed the interaction appears to be synchronized. Two individuals desperately trying to avoid one another, but succeeding only in mirroring each other's movements and remaining in one another's path until one individual steps aside and allows the other to pass. What makes two individuals who are behaving independently become a synchronized unit? (Oullier & Kelso, 2009). The coordination of social interaction between individuals is a common every day aspect of one's life (Oullier, de Gutzman, Jantzen, Large & Kelso, 2008; Richarson, Marsh, Isenhower, Goodman & Schmidt, 2007; Wolpert, Doya & Kawato, 2003). The amount of practiced and perfected coordination (Schmidt, Carello & Turvey, 1990) represented by a group participating in sports, or listening to music, or dancing is quite obvious (Schmidt et al., 1990). Wiltermuth & Heath (2009) suggested that synchronized movements may have a positive effect on individuals, reducing psychological boundaries between oneself and the group. With the indication that synchronized movement enhances group consistency, connection and positive emotion (Wiltermuth & Heath; 2009) can it also be said that individuals who "march to the beat of their own drummer" are out of synchronization with the rest of society? Are these same individuals potentially unable to experience the group consistency, connection or positive emotions that may be generated from the coordination brought about by social interaction? Or is the fact that they are out of synchronization with the rest of society that actually makes them in-sync with society?

Socializing and communication in regards to motor movement can cause others to avoid or be timid around children with ASD. First, there are motor impairments that present as fine motor deficits in manual dexterity and ball skills (Manjiviona & Prior, 1995; Green, Baird, Barnett, Henderson, Huber,& Henderson, 2002; Miyahara, Tsujii, Hori, Nakanishi, Kageyama & Sugiyama, 1997), reach and grasp tasks (Mari, Castiello, Marks, Marraffa & Prior, 2003), and bi-manual load-lifting (Schmitz et al., 2003). Gross motor impairments can be displayed in the form of awkward walking/running gait (e.g. limited to no arm use, choppy strides, decreased pace, clumsiness) (Gillberg, 1989; Hughes, 1996), poor balance, coordination, and posturing (Ghaziuddin & Butler, 1998; Green et al., 2002; Manjiviona & Prior, 1995; Miyahara et al., 1997; Maurer & Demasio, 1982). Motor impairment can be mild or severe and vary like all characteristics and symptoms per individual with ASD. Movement deficiencies are often associated with communication issues related to children with ASD for the simple reason of visibility, as one of the first things people notice when communicating with others is the way they move.

> Movement is the only way we have of interacting with the world, whether foraging for food or attracting the waiter's attention. Direct information transmitted between people, through speech, arm gestures, or facial expressions is

> mediated through the motor system which provides a common code for communication (Wolpert, Doya & Kawato, 2003, p. 305).

Motor behaviors that lead to problems with socialization for children with ASD are generally thought to be brought on by ineffective interaction (Thompson, 2011) such as self-stimulated stereotypical mannerisms (e.g. hand flapping, pacing, spinning, rocking, toe walking, etc.) (Hyman & Towbain, 2007; Thompson, 2008; Thompson, 2011). While these meaningless behaviors are not considered socially acceptable they generally do not cause any immediate harm, other than possible social isolation (Donnellan, Hill & Leary, 2013). However, at the other end of the self-stimulating behavior social spectrum is that of self-injurious behavior in which a child with ASD repeatedly causes injury to themselves (e.g. head banging, self-biting, scratching, pinching, etc.). Once again, these mannerisms are not considered socially acceptable. Many children with ASD display some form of individualized motor impairment ranging from the smallest almost unnoticeable tic to a very obvious gross motor irregular walking gait/posture (Buderath, Gartner, Frings, Christainson, Schoch, Konczak & Gizewski, 2009; Gillberg, 1989; Hughes, 1996; Hyman & Towbain, 2007; Thompson, 2009; Thompson, 2011). Limitations such as these may not enable an individual with autism to experience a direct immediate personal connection with another person setting up opportunity for failure in communication and social situations (Williams, White, Suddendorf, & Perrett, 2001).

This review of literature is not intended to be comprehensive, but rather takes a further look at previous studies in the areas of synchronized rocking and movement, social coordination and behavior, and the effects they have on children with ASDs ability to communicate with others. Contributions these studies have made to research will serve as foundations and guides considered to be relevant to the present study summarizing current areas of interest that focus on social behavior and motor coordination in children with ASD.

Historical Influences

Historical influential studies regarding motor limitations and social deficits associated with children with ASD have been in effect for the past 60 plus years (Thompson, 2011; Wolff, 2004). Autism Spectrum Disorder was initially recognized due to the research Leo Kanner conducted on a group of children in 1943 (Blancher & Christansen, 2011; Kanner, 1943). During his observations of these children Kanner described general characteristics displayed by all the children. These characteristics include, but are not limited to: reduced to no response to others, non-practical to no gesturing, no eye contact, delays in to no verbalizations, repetitive movement patterns (i.e., finger tapping, head shaking, arm flapping, etc.). Kanner also noted that during his observations the children displayed what could be perceived as a “clumsy gait” (Blancher & Christansen, 2011) hinting at possible gross motor impairment. While his research suggested that the gross motor deficiencies, reflected in the abnormal gait of children with ASD, were a characteristic that warranted further investigation, many of the studies conducted in the 1960s and early 1970s were influenced by the psychodynamic theories that ASD was a form of schizophrenia found in children (Bettelheim, 1967; Blancher & Christansen, 2011; Kim & Lord, 2013; Wolff, 2004). While there was an increased interest in ASD research, including movement behavior and socialization during this time it unfortunately, was not substantial enough to get ASD recognized in the first two versions of the American Psychiatric Associations Diagnostic and Statistical Manual of Mental Health Disorders (Blancher & Christansen, 2011; DSM-I, 1952; DSM-II, 1968). Rimland's (1964) research an exception to most studies done during that time, suggested that children with ASD exhibited coordinated, lithe motor skills. Studies conducted in the later 1970s conflicted with Rimland's study as the results from these studies revealed children with ASD to have awkward gaits, odd upper body posturing while walking, slower pace and decreased stride length (Damasio & Mauer, 1978; Vilensky, Damasio & Mauer, 1981). The mid-1970s witnessed the opportunity for educational and therapeutic interventions provided through the U.S. Developmental Disabilities Act of 1975 (Blancher & Christansen, 2011; U.S. Department of Education, 1990). In 1981, Lorna Wing introduced Asperger's and furthered the epidemiological concepts of ASD (Blancher & Christansen, 2011; Wolff, 2004). The late 1980s and early 1990s not only saw the advancement in genetic research (Rutter, 2004) it also saw the revamping of some professional journals and founding of others including the Journal of Autism and Developmental Disorders (founded in 1971 under a different name), Autism: the International journal of Research and Practice (1997), Focus on Autism and Other Developmental Disorders (1985), and the International Autism Research Review (1987), among others (Wolff, 2004).

The 1990s also established a shift in interest to concentrate on collecting information regarding motor behavior and motor development skills, with emphasis on the effects research findings would have diagnostic criteria today (Baranek, 2002;

Berkeley, Zittel, Pitney & Nichols, 2001; Leary & Hill, 1996; Manjiviona & Prior, 1995; Mari, Castiello, Marks, Marnaffa & Prior, 2003; Teitelbaum, Teitelbaum, Nye, Frymann & Mauer, 1998). Leary and Hill suggested that impairments in motor function may have an influence on core characteristics of autism (1996). Miyahara et al. (1997) examined children with autism and found that they scored below the 15th percentile on the Movement Assessment Battery (Henderson & Sugden, 1992) which is indicative of a problem with motor functioning. Baranek (1999) used home video assessments to evaluate sensory motor functions of children with autism. Results from her study showed children with ASD to display odd behaviors during sensory motor functioning. Behaviors included limited visual attention and tracking, delayed response to others who are trying to engage them, excessive mouthing of objects, and dislike to being touched in social situations. Another study suggests that children with autism, especially those who are higher functioning have a problem with executive functioning (Hughes & Russell, 1993). Hughes (1996) reported that children with autism often display “motor clumsiness” which in keeping with impairments in executive function, “failure to predict movement or having impaired visual control of movement” (Rinehart, Bradshaw, Brereton & Tonge, 2001, p. 81) hints at the possibility that perhaps it is not the physical ability to perform that is lacking, but rather a neurological disorder (Ghaziuddin & Butler, 1998).

There have been substantial advancements in the clarifications of diagnostic criteria, name changes, creation of sub groups, and overlap that may potentially occur with other disorders (American Psychiatric Associations DSM-III, 1980; American Psychiatric Associations DSM-IV, 2000; American Psychiatric Associations DSM-V, 2014; Blancher & Christansen, 2011; Wolff, 2004). However, despite all the advances in ASD research with regard to movement coordination and social behavior, limitations in movement tasks are still considered a secondary condition (American Psychiatric Associations DSM-III, 1980; American Psychiatric Associations DSM-IV, 2000; American Psychiatric Associations DSM-V, 2014; Provost, Heimerl & Lopez, 2007; Provost, Lopez & Heimerl, 2007).

Theoretical Influences

There are a wide array of theoretical influences that have been used to explain the various aspects of ASD. However, for this review of literature three theoretical perspectives were chosen based on relevance to the present study and their involvement within the areas of movement synchronization, social and behavior coordination, and the effects they have on the senses of children with ASD. The three theories include the Theory of Behavioral Dynamics, The Theory of Autism, and The Interdependence Theory.

Movement Synchronization

The Theory of Behavior Dynamics which describes a behavior of rhythms or "configurations of change, where body elements sustain and change movement together in an ordered fashion. It is this variable and serially-emerging pattern of sustaining and changing together which seems to constitute the "units" of behavior" (Condon & Ogston, 1966, p. 341). This theory was utilized as a foundation of literature for the present study due to the impact it has had on other studies involving coordinated human movement

(Schmidt & Richardson, 2006). While behavior dynamics in relation to movement coordination can be examined from a variety of perspectives (i.e. behavioral attractors, phase transitions, frequency of oscillations, etc.) (Haken, 1977; Haken, 1983) the relevance to the present study was the relation of relative phase angles formed between the two oscillators (i.e. more specifically the rocking chair sensors) and the mathematical process utilized to determine rocking chair sensor locations throughout each of the trials during the study.

The Haken, Kelso & Bunz (1985) study lends support to behavior dynamic studies as it introduced the mathematical equations and functions known as the Haken, Kelso & Bunz (HKB) equation. The HKB equation (i.e., $\dot{\phi} = -a\sin\phi - 2b\sin 2\phi$) was utilized in many of the coordinated and interpersonal movement studies conducted more recently (Marsh et al., 2013; Schmidt et al., 1990; Schmidt, Christianson, Carello & Turvey, 1994; Schmidt & Richardson, 2006; Richardson et al, 2007). The HKB equation allows for study analysis for "movements of the individuals and the coupling that occurs between them" (Haken, Kelso & Bunz, 1985, p. 351). The present study utilized a modified version of the HKB equation during the set-up and analysis process (further discussion begins on page 41).

Social and Behavior Coordination

The Interdependence Theory examines the structure of interpersonal situations and how these situations affect the individuals interacting in these social environments (Kelley, Holmes, Kerr, Reis, Rusbult & Van Lange, 2003; Kelley & Thibaut, 1978). The Interdependence Theory also "provides a good frame work through which to investigate phenomena associated with social coordination" (Finkel, Campbell, Brunell, Dalton, Scarbeck & Chartrand, 2006, p. 456).

"Social coordination refers to the coordination of one's actions with the actions of another person in completing a task together" (Reis & Collins, 2004). Social coordination in its simplest form is defined as a of form of social communication involving a pair or dyad of individuals who "execute rhythm" (Oullier et al., 2008) during interaction (e.g. movement coordination, postural coordination, verbal synchronization during conversation, etc.). All social activities require coordination and the efficiency of this coordination to a great extend influences the performance (Kelley, Holmes, Kerr, Reis, Rusbalt & Van Lange, 2003). Social coordination can be viewed as a complex matrix that comprises joint attention, cognitive behavior, coordination dynamics, and social psychology (Oullier & Kelso, 2009).

Joint attention has been deemed in some groups to be essential for successful communication (Brown, Schmidt, Campana & Tanenhaus, 2004; Clark, 1996). Joint attention is defined as the action(s) performed by an individual or others around them that serve to attract attention (Richardson, Dale & Kirkham, 2007). Actions used in joint attention can be noticeably obvious examples may include waving and pointing while other actions may be less noticeable, such as, eye tracking during a conversation about a shared visual display (Hari & Kujala, 2009; Richardson et al., 2007). Research of joint attention indicates that "when two individuals sit side by side viewing a display, the speed of one individual's response is affected by features that are irrelevant to their own task, but relevant to the other persons" (Marsh, Richardson & Schmidt, 2009, p. 1219).

This suggests that the pair is influenced by each other and have an increased chance of synchronizing their movements.

Cognitive behavior focuses on the interference and transfer that takes place during motor adaptation in performance (Howard, Ingram & Wolpert, 2011). Oullier and Basso (2010) suggest that in real social life situations bodily movements, posture, sensitivity to imitation conveyed by the body combined with the physical presence of others has a great amount of influence on the actions and decisions of individuals. Behavior cognition analyzes all relevant information during social interactions “maximizing an individual’s ability to predict the action outcomes of others so they know how to act in response themselves” (Beilock, 2008, p. 21).

Coordination dynamics is “an overarching conceptual framework that describes, explains and predicts how patterns of coordination form and change at multiple levels of brain and behavior” (Oullier & Kelso, 2009, p. 8199). Cooperation dynamics are organized into three levels. The first is information exchange which deals with informational quantities including mass, height, length and time and how they relate to various systems of communication (Oullier & Kelso, 2009). The second level involves phase transitions which are spontaneous changes from one coordinated movement pattern to another (Fuchs & Jirsa, 2004; Oullier & Kelso, 2009). The third level of coordination dynamics also known as the “key concept” (Oullier & Kelso, 2009, p. 8199) is stability. Stability indicates whether a phase transition will or will not occur within a system. Stability also measures the time (after a perturbation) a system takes to return to its initial or state of relaxation.

When working together the aspects of behavioral dynamics, social and behavior coordination form the mechanics of social interactions for dyads. First an individual acknowledges the movements of another person interpreting goals, beliefs and emotions. Next, the individual produces a behavior response that possibly mimics the other person and relays some form of understanding. Finally, the loop of communication comes full circle in that the individual reacts and responds to the behavior initially observed in their partner (Barsalou et al., 2003).

Stimulus and Their Effects on the Senses

The Theory of Autism is one that can be considered ever changing and evolving based on the perspective from which it is being viewed, studied, and the level of ability displayed by the individuals to whom the theory is referring at any given point in time. Donnellan, Hill & Leary (2013) refer to the Theory of Autism as a recognition of an individual's ability, functionality, level of development, and how their "communication, relationship, and participation require neurological systems to coordinate and synchronize the organization and regulation of sensory information and movement" (p. 1). A societal interpretation of what characteristics an individual with ASD displays and is deemed acceptable or not has in essence built the Theory of Autism.

While it is clear that individuals who have to separate nervous systems can have observed patterns of coordination, the source of coordination being observed is undefined. However, despite the actual type of coordination taking place (e.g. movement coordination, postural coordination, verbal coordination during conversation, etc.) patterns of coordination depend on the individuals interacting, how they perceive their environment, and how they perceive each other. Perception is based on the senses which what allows them to identify, acknowledge, interpret and respond to all noted stimulus around them. The senses are also important for communication and defining social coordination.

While all senses are used in communication some are more understood and therefore used more often in defining social coordination. Olfaction though important in many species is not fully understood in humans though those who tend to smell better seem to be more pleasing and are more apt to be accepted in social situations (Hari & Kujala, 2009). Certain smells can act as distractors for children with ASD who have heightened sensitivity to senses. Generally, senses utilized more frequently in the study of social coordination include listening, which is tied to vocal language, vision, which is used in both verbal and non-verbal communication, and touch (Hari & Kujala, 2009; Richardson et al., 2007; Tognoli, 2004). According to Clark "language is really a form of joint attention" (1996, p. 3) that can serve as a coordination device in reaching a common goal (Clark, 1996). During conversation, individuals will vary speaking rate, pitch and intensity of vocalizations to convey importance and meaning (Shockley, Santana & Fowler, 2003). McGarva and Warner's research demonstrates that during dyadic conversations individuals tend to act as time keepers. This refers to the cycling or rhythm of the conversation or the amount of time each individual spends talking (vocally active) and listening (vocally inactive). Cycles typically range from two to six minutes. The longer the conversation the more likely the couple conversing will develop an active and inactive vocal rhythm or synchronicity. McGarva and Warner also suggest that "some dyads may have an easier time conversing than other dyads because of a similarity in preferred cycle rates (2003, p. 337). Can the same be true for dyads interacting in coordinated movement environments?

Communication involving vision (e.g. directional gaze and eye tracking, etc.) can be used verbally or non-verbally. Vision used with verbal communication enhances the social interaction by either allowing the listener and speaker to maintain eye contact or by developing a systematic link between the topic of the conversation and the conversers' eye movement (Richardson et al., 2007). In non-verbal interaction social interaction vision serves as a communication aid in interpreting "attitudes and feelings via gestures, actions, postures, and expressions" (Hari & Kujala, 2009, p. 460) of other individuals. Vision is also an important factor in movement coordination during social interaction (Hari & Kujala, 2009). During the ritualistic movements of every day behavior individuals often find themselves in a synchronized rhythm with the other individuals around them (Hari & Kujala, 2009; Oullier et al., 2009). This type of coordination can be "intentional and controlled through physical contact (e.g. when individuals are ballroom dancing) it can also be unintentional and occur during a visual interaction" (Richardson et al., 2007, p. 868). This suggests that individuals can coordinate and execute in-phase and anti-phase movement through interpretation of visual information (Marsh et al., 2009; Oullier et al., 2009; Richardson et al., 2007). Research shows that dyadic groups spend more time in coordinated movement states when they have focal visual information about their partner's movement. This is comparable to the decreased time in coordinated movement states when they have only peripheral visual information about their partner's movement (Marsh et al., 2009; Oullier et al., 2008; Richardson et al., 2007).

Auditory coordination occurs through listening and hearing what is happening in the surrounding environment. Research studies utilize auditory signals during coordinated movement studies to test reaction times between participants (Schmidt et al., 1990; Temprado and Laurent, 2004). People in everyday situations use auditory coordination to interact with people around them. It is important to note that not all communication or coordinated patterns involving auditory coordination involves being able to see the other person (e.g. having a phone conversation, performing a study while blindfolded) sometimes it is the persons verbal instruction or a rhythmic beat that allows for coordinated patterns to occur between individuals.

While research supports that social coordination takes place between individuals in both in-phase and anti-phase synchronization studies (Fuchs & Jirsa, 2004; Kelso, de Guzman, Reveley & Tognoli, 2009; Oullier & Kelso, 2009; Richardson et al. 2007) the question arises of whether individuals who are not socially developed, who are afflicted with social anxiety (Demetriades, 2002; Lee, 1997; MacGregor, 2001) or who have a disability that impairs social interaction (Schmidt, Christianson, Carello and Baron, 2007) can coordinate movements with another individual who may or may not be socially inhibited. Though there are limited studies of social coordination involving individuals who are in some way socially impaired, previous research suggests that there is a division in thinking in regard to whether socially impaired individuals are able to perform socially coordinated synchrony with a partner. Some researchers suggest that individuals who have serious communication disorders, problems with social interaction or those who suffer from psychological pathologies not only "appear to be less internationally synchronous than normal" (Condon, 1982), but also "their disability does not allow for a dyadic synergy to emerge in their interactions with others" (Schmidt et. al, 2007, p. 161). It is also believed that "the core of the disorder defines the condition and likely affects the development and expression of other skills" (Klin, Jones, Schultz, Volkmar & Cohen, 2002, p.895). While other research indicates further interest in whether the paradigms of social synchrony and cooperative social action have a psychological connection to the individuals in dyads pairings that are put into similar movement situations (Marsh, Richardson & Schmidt, 2009; Schmidt et al., 2007). Schmidt et al. hypothesized that "coordinating and cooperating should be linked to feeling more connected with others. Moreover, individuals who are predisposed to connect with others (or have difficulty doing so) should display stronger (or weaker) pull to coordinated movement and joint action" (2009, p. 328). This suggests that when two individuals are similar in attitudes toward specific subjects and "preexisting dispositional tendencies in sociality dimensions of personality" (Marsh, Richardson & Schmidt, 2009) they are more likely to reinforce each other's beliefs, therefore, likely to be more attractive to each other which in turn leads to similarity in both verbal and non-verbal communicative behavior (McGarva & Warner, 2003; Singer, Wolpert & Frith, 2004). Whereas, if the two individuals are not similar in interests, beliefs and skill in social interaction there is a decreased chance for communication, increasing the likelihood of relationship failure resulting in limited social interaction or coordination (McGarva & Warner, 2003; Schmidt, Christainson, Carello & Baron, 1994; Tognoli, 2004).

"An important problem in human social behavior concerns understanding the degree to which an individual influences the actions of a group (i.e. peer group, family, class, dyad, etc.) he/she is in" (Oullier & Kelso, 2009, p. 8208). In social hierarchical systems emergence of the leader-follower roles suggest that "social interaction requires both a willingness to give (e.g. follow) as well as the ability to take (e.g. lead) suggesting a more successful coordination when the individuals' social coordination levels are complementary" (Schmidt et al., 1994). This implies that individuals who emerge as leaders are most likely to dominate, lead, control and influence individuals around them when necessary to resolve issues and complete tasks to a satisfactory level (Oullier & Kelso, 2009; Schmidt et al., 1994). Furthermore, individuals who are followers are more likely to submit or acquiesce due to lack of skill, competence or motivation (Hari & Kujala, 2009; Oullier & Kelso, 2009; Schmidt et al., 1994). The study by Schmidt et al. "suggests that high social coordination in and of itself does not guarantee interactional synchrony; instead, complementary social coordination levels seem to produce higher degrees of coordination than matched levels" (Schmidt et al., 1994). Dyad groups with two leaders would possibly compete for control while the dyad group with two followers may lack the willingness to take control (Oullier & Kelso, 2009; Schmidt et al., 1994). Considering the leader-follower view of social coordination the possibility of an individual who is socially impaired paired with an individual who has no social problems producing socially coordinated synchronized movement does exist.

Social impairments affect each individual differently. While some remain on the edge of social activity never really engaging (MacGregor, 2001) others will choose to avoid it all together (Beal, 1998; Lee, 1997; MacGregor, 2001). However, the more that is learned about social impairment and the environments in which they occur the greater the chance of reducing some of the barriers that inhibit individuals with ASD from engaging in social settings.

The following studies served as a foundation for movement behavior and interpersonal coordination for which the present study was built. While none of the studies mentioned were exact in their incorporation of variable aspects relating to the present study, however, each contributed specific perspectives that were taken into consideration when developing the focal points for the present study, thus they are presented more in depth.

Schmidt, Carello & Turvey's (1990) "examined the influence that visual perception had on oscillating limb coordination in between-subject experiments to determine if the outcome results would be comparable to those from previous within-subject studies" (p. 227). The results of this study revealed that the phasing of limbs between two people can be characterized by the same properties found in the phasing of limbs within a person. These properties from within-person coordination include alternate and symmetric phasing. The alternate phasing was reported as less stable as shown by the breakdown of phasing to the symmetric phase during high frequencies of oscillation. During the experiments when performing at a faster rate there is a point where the alternate phase can no longer be maintained resulting in only the symmetric phase of movement.

Schmidt, Christianson, Carello & Baron (1994) examined the "effects of social and physical variables on between-person visual coordination" (p.159). The goal of this study was to "determine how the degree of between-person coordination or interactional synchrony changes with social or personality variables" (p.159). Results of this study show that "the strength of the dynamic was generally greater for the in-phase than the anti-phase mode and decreased with increasing frequency. Further, the strength of the interpersonal inter-limb coupling was weaker than that of intrapersonal inter-limb coupling" (p.159) demonstrated during the experiments.

Richardson, Marsh, Isenhower, Goodman & Schmidt (2007) examined pairs of participants who rocked in rocking chairs during the experiments. In the experiments of the study the pairs of participants were instructed to intentionally rock either in-phase or anti-phase with each other while utilizing focal and peripheral vision in the each series of trials. "The results of the visual focus manipulations indicate that the stability of a visual interpersonal coupling is mediated by attention and the degree to which an individual is able to detect information about a co-actor's movements" (p. 867). The results supported the initial thought that patterns involving intentional and unintentional visual coordination can be reflected in the perceptions and motor coordination as demonstrated by pairs of participants in the study.

Coordination levels between children with ASD and TD children was the topic of study for Isenhower et al. (2009). This study examined 30 children (27 with ASD and 7 TD) who were matched with their parent for the test of interpersonal coordination. The child and parent sat in rocking chairs side-by-side, the parent listened to a metronome beat via headphones and was instructed to rock in time with the beat. The child was not given any instruction other than to sit in the rocking chair next to their parent for the duration of the test. This allowed the researchers to observe potential rocking patterns of the children. Would the children rock? If so, would they set a pace comparable to that of their parent? The results of this test revealed differences between children with ASD and TD children. While the children with ASD did rock, they did not rock in a synchronized manner with their parent nor did they exhibit any particular relation to the rocking pattern set by their parent. The TD children rocked most of the time and maintained a rocking pattern similar to that set by their parents.

Demos et al. (2011) examined the effects that music had on participant's ability to coordinate their rocking movements with a partner while being exposed to trials with music, no sound, and the sound of their partner rocking. These also included a visual component where in some of the trials the participants could see their partner and others where they could not. Conclusions to this study showed that when partners were able to see and hear their partner rock they "elicited spontaneous coordination, and the effects of hearing amplified those of seeing" (p.49). Further conclusions showed that coordinating with music was weaker than coordinating rocking movements with a partner, "and the music competed with the partner's influence, reducing coordination" (p.49).

Chang, Wade, Stoffregen, Yu-Hsu, and Yu-Pan (2010) investigated the differences of postural sway in children with ASD and TD children during two different suprapostural visual tasks, visual searching and visual inspection. In comparison to the present study both studies were experimental in the tasks they had participants perform and the relationship between motor ability and social coordination. The assumption of the Chang et al. (2010) study was that the visual tasks would require more control of gaze (i.e., eye fixation and movement), thereby, reducing postural sway during testing. The results revealed that both children with ASD and TD children "were able to functionally modulate postural sway to facilitate the performance of a task that required higher perceptual effort" (p. 1536). These outcomes are comparable to those of the present study in that there was little difference between the overall synchronization abilities of children with ASD and TD children.

This last study conducted by Marsh et al. (2013) discusses the possibility of timing deficiencies having an impact on the ability of children with autism to “socially connect” with those individuals around them. Participants in this study included children with autism, children who are typically developing, and the caregivers of the children (i.e. parents and guardians). The caregivers were paired with their child and asked to read a book to them while rocking to a metronome that only they (the caregiver) could hear. Rocking coordination and patterns of trial pairs were recorded for the duration of the book being read which lasted from 2-5 minutes depending on the length of the book. Results from this study indicate that children who are typically developing display a significantly greater in-phase rocking behavior with their caregivers than children with autism. Likewise, Children who were typically developing showed a greater degree of timing and tempo matching with their caregiver than children with autism. The authors also suggest that “at rather fundamental low-level motoric behavior that does not depend on intentional goal-directed action, there are deficiencies in the social grounding of ASD children’s movements” (p.10). However, they also suggest that more research is needed on this subject.

The relationship of degree bin endpoints for TD and ASD is established by the “foundation of all society’s activity which is the physical, motor coordination of people in social interactions” (Schmidt & O’Brien, 1997, p. 189). Whether an individual is TD or ASD, societal interactions provide the basis for greater rapport and effective social coordination (Semin, 2000; Wilson & Knoblich, 2005) that occurs when interested participants (i.e. those willing and motivated to interact with each other) are placed in environments and situations where some form of cooperation and communication is required. Interpersonal coordination may also afford other cognitive advantages to the interacting partners; (i.e. perceptual emulation, observational learning, and enhanced planning and anticipatory control in joint tracking tasks, c.f. Miles et. al., 2009). Wilson (2001) adds that coordination of actions with another may enhance the dynamics of knowledge communication during social interaction. The Isenhower et al. (2012) study revealed that children with ASD tended to display increased variability of drumming speed when compared to TD children during such a coordinated rhythmic activity. Their study also suggests that children with ASD are not readily able to coordinate movement interpersonally which adds support to the reason why "children with ASD do not synchronize their movements with other individuals or environmental stimuli" (p. 30) compared to TD children who appear better able to synchronize their movements with others. A study by Marsh et al. (2013) concluded TD children were better able to coordinate rocking movements with their parents, than children with ASD.

Conclusion

"A profound aspect of human social behavior is our ability to coordinate our movements with another person" (Schmidt et al., 1994, p. 160). However, more studies are needed to determine the level(s) of coordinated movement patterns in dyads involving individuals with ASD. Studies may find that individuals with ASD may exhibit more coordinated movement with a partner while using peripheral vision as opposed to direct vision. People with ASD learn through imitation, so it is possible they may be able to synchronize their movement through mimicry. In individuals with ASD who are "characterized by abnormal social attention and social meanings, or both a better understanding of the mechanism of social interaction would be relevant for teaching, training, and therapy as well as for understanding social conflicts and the effects of dyadic interactions during e.g. trainee-master and patient-therapist relationships" (Hari & Kujala, 2009, p. 455) as the more these individual's movements and behaviors are understood the less different they will appear be to the rest of society.

CHAPTER III

METHODS

Participants

Twenty participants, from a Northern Minnesota school district, volunteered to take part in this study. Ten children diagnosed with ASD (males = 10, females = 0) and ten TD children (males = 5, females = 5) comprised the experimental and control groups respectively (See Appendix H). Prior to beginning the testing phase of the study, which took place at a local High School Building, all participants were read an assent form, and had a signed parental/guardian consent form on file. Participants weighed 81 pounds or less due to the weight limitations on the rocking chairs used in the study. The age range for all participants was 7-11 years with the mean age for children with ASD 7 years 8 months, and for the TD children 8 years 2 months. The children with ASD had an I.Q. > 60; children with ASD who have an I.Q. < 60 are generally non-verbal (Böckler, Timmermans, Sebanz, Vogeley & Schilback, 2014; Miles et al., 2005) and are approaching the cut off point for developmental deficiency (Klin et al., 2007). Such individuals would not be able to comply with instructions or remain on-task without interruption (i.e. rocking, arm flipping, finger tapping, etc.) (Bass & Mulick, 2007; Kern, Koegel, Dyer Blew & Fenton, 1982; Klin et al., 1995; Macintosh & Dissanayake, 2006).

All participants were healthy and physically capable of rocking in a rocking chair; had 20-20 vision, with only one with vision corrected to 20/20. All of the participants had normal hearing.

Rocking Chair Set-up

Data collection employed a Polhemus 3 Space Fastrak System (Polhemus Corporation, Colchester, VT). The Polhemus (also referred to as Bird unit), was a magnetic tracking system, operated in conjunction with a Flock of Birds (FOB) computer system to record the motion of the rocking chairs. The FOB is a motion tracker computer graphics application (Ascension Technology Corporation, Burlington, VT) interfaced with Microsoft Windows technology. The FOB comprises a six-degrees-of-freedom measuring device that can be configured to simultaneously track the position and orientation of multiple sensors by a transmitter (Ascension Technology Corporation, 2002). In the present study the FOB was set up as a “Standalone” which utilized a single Bird unit with its own transmitter and two sensors connected via a RS-232 port interface (Ascension Technology Corporation, 2002) to a host computer. The host computer used for this study was a Dell Inspiron 1525 laptop.

The transmitter was a 2 in. grey cube connected to a cable. That remained in a fixed position (i.e., on top of the tower) throughout the data collection process. The transmitter created an electro-magnetic field and provided the position and orientation measurements of the sensors on the anterior-posterior (AP) (i.e., X coordinate) medial-lateral (ML) (i.e., Y coordinate), and the vertical motion (VM) (i.e., Z coordinate) planes (Ascension Technology Corporation, 2002).

The sensor was about the size of a quarter connected to a cable; the position and orientation of each sensor was measured relative to the transmitter (Ascension Technology Corporation, 2002) during data collection.

The two rocking chairs used in this study were Kid Kraft Spindle rocking chairs (29-3/4"H X 23-1/2"L X 16-1/4"W) with a maximum weight capacity of 81 pounds. The chairs were chosen for their "child size" proportions which allowed participants to sit in a natural position with their knees bent at a 90 degree angle, feet flat on the floor, backs flush against the back of the chair, and arms resting either on their laps or on the armrests of the chair (also see consent form Risks Section).

In order to assess each participant's ability to rock, a metronome was used to as an external pacer while each child practiced his or her ability to rock backwards and forward. All participants demonstrated their ability to achieve this rocking motion.

A Franz Crystal Metronome, Model EM-900 (Franz Manufacturing Corporation, Inc., New Haven, CT) set at 60 beats per minute was used for pacing. Based on previous research studies, 60 bpm provided a comfortable rocking tempo (Demos et al, 2011; Marsh et al, 2013).

A Canon FS300 digital video camcorder with a mini table-top tripod (6") recorded all trials so that they could be reviewed at a later date/time if necessary. The video recordings maintained the anonymity of all participants.

Testing Area

Figure 1 illustrates the testing area and location of the recording apparatus. The study was conducted in a 10 X 14 multipurpose room with white concrete walls on three sides. The fourth was floor-to-ceiling windows which were covered by blinds that were kept closed for the duration of the study. The ceiling was covered in tile and energy saving white lights with sensitivity coverings. The floor was covered with carpet that eliminated the sound of the rocking chairs (Demos et al., 2011) while the participants were rocking.

Room and Equipment Setup

Room setup began by measuring 3ft. from the end wall and taping a 7ft line on the floor running parallel to the wall (Figure 1). The center point of this line was located at 3ft. 6in. and marked. From this center mark a 4ft. line was taped perpendicular to the existing 7ft. line. At the opposite end of the 4ft. line is where the center mark on the base of the tower was lined up, placed, and secured.

Located on a wooden tower (2ft. 11.5in. high) the transmitter box was attached via Velcro bindings, reinforced with duct tape. The transmitter cable was attached to the Bird unit via RS-232 port, located on top of the table located 2ft. behind the tower. The Bird unit was located on top of the table located 2ft. behind the tower. The Polhemus/Flock of Birds system was also synchronized. For a detailed description of the systems setup see Appendix D.

Going back to the original 7ft. tape line, 1ft. 3in. was measured from the center mark along the tape line in both directions and marked. From each of these two marks a 2ft. line was taped to the floor perpendicular to the original 7ft. line. The two 90 degree angles created by these tape lines was where the front and outside of the inner rocker of each chair was lined up in order to synchronize the system at the beginning of each trial. When the chairs were placed on their starting marks they were 2ft. 5in. apart from the outside of the inner most rocker on each chair.

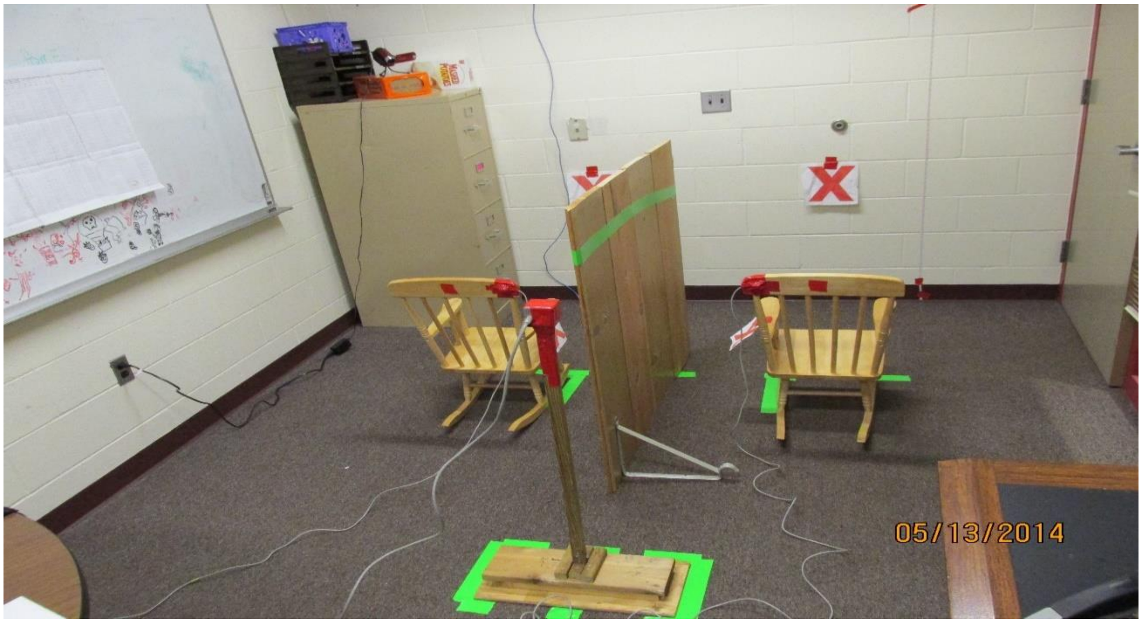
The chairs were placed in a 90 degree starting location and a sensor was attached to the headrest of each chair. One sensor was attached on the inner backside, 1in. down from the top edge and 1in. in from the inside edge of the headrest. In order for the sensor to accurately and correctly collect the data the tails (i.e. cable connections) of the sensors were pointed at a 90 degree angle perpendicular to the inside edge of the headrest. Sensors were secured to the headrests with duct tape and the sensor cables were attached to the Bird unit via RS-232 ports.

For the rocking practice a removable wall divider (3’7”H X 4’ L X 1”W) was placed directly between the rocking chairs (one top of the 4ft. line taped to the floor) to separate participants from seeing each other. Once the practice condition was completed the wall divider was removed.

The camcorder fixed atop a mini tripod was located on top of the cabinet in the left-front corner of the room with the camera angled downward for the best view of participants. The camera was turned on prior to the participants entering the room and turned off after they had left in order to reduce any distractions.

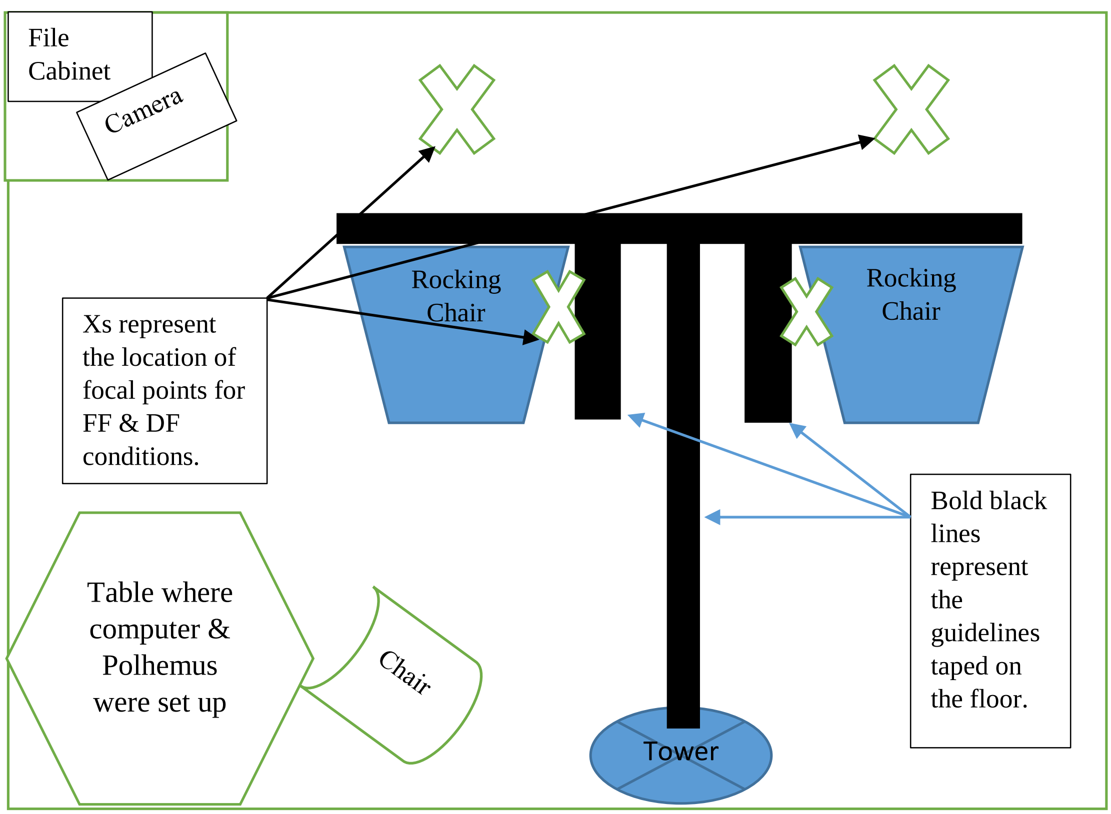
Vision direction was manipulated using a red “X” during the Forward Focus (FF) and Direct Focus (DF) conditions. A red “X” (7” X 7.5”) was attached to the wall directly in front of each participant’s chair positioned 3ft. from the floor to be used during the FF condition. A red “X” (4” X 4.5”) was attached to the outside of the inner armrest of each participant’s rocking chair to be used during the DF condition.

Figure 1



Test site: this set up has the divider (above) in place for the Baseline trials as well as tape marks on the floor for equipment set up.

Below is the layout of the test room and position of equipment and tape marks.



Data Collection

The AP, ML, and VM data (i.e., X, Y, and Z coordinates respectively) were collected at a sampling rate of 60 Hz per second for a period of 2 minutes for each trial yielding approximately 7200 data points per coordinate value (i.e., X,Y and Z), per subject, per trial. The collection process was initiated by "clicking" the red dot (start/stop button) on top of the left side of the screen. An internal clock/timer within the FOB system kept track of time for the 2 minute duration of each trial. The data collection/recording was terminated at the end of each trial by the researcher "clicking" the red dot (start/stop button) on top of the left side of the screen. At the end of each trial, data collected was named and saved to the study file.

Procedure

Prior to arriving at the testing site participant's parents were asked to read and sign a consent form (See Appendix A) allowing their child(ren) to participate in the study. Both the assent form and consent forms used in this study were approved by the Institutional Review Board (IRB) from the University of Minnesota and the host school district assisting with this study. The children were randomly assigned a testing time and were given notice a week in advance to arrive on site to participate in the study.

Upon arrival to the test site participants were greeted by the researcher and introduced to each other. The researcher then read the assent form (See Appendix B) and asked if they understood what they were asked to do during the study. Due to the limitations of some of the participants, they were asked to give a verbal response to participating in the study rather than signing the assent form. All participants responded that they understood and were ready to begin. The participants were each assigned a rocking chair for the duration of the testing phase and the rocking condition instructions (See Appendix C) were explained. Participants were not informed as to the purpose of the test. Once the practice session was completed the participants were allowed to stand and stretch while the dividing wall was removed. The participants were asked to sit back down in their assigned chairs and the instructions (See Appendix C) for the experimental conditions to be tested were explained. Due to the randomization of conditions (i.e. FFWM, FFNM, DFWM, and DFNM) the order in which they were introduced was different for each pair of participants. When all four conditions were completed the participants were thanked for their participation in the study.

Rocking Practice

Rocking practice (with and without metronome) was used to establish each participants rocking pattern. Participants sat in the rocking chairs in correct form. They were instructed to rock at whatever pace was comfortable for them. There were no requirements for where they were to look during the six baseline trials. During the six trials (three with the metronome and three with no metronome) all the participants had to do was rock at their preferred pace. When they heard the command “start rocking” they began to rock and continued to do so for the next 120 seconds. The command “stop rocking” was given at the end of 120 seconds at which time the participants stopped their rocking motion and remained seated until further instruction was given. This process was repeated for each baseline trial. The recorded data from each trial was saved to an excel study file. After the six trials for the two BL conditions were completed the wall divider was then removed in preparation for the next four conditions and participants were given a rest period of 3 minutes.

Research Design

The dependent variable in this study was the level of rocking synchronization measured as the relative phase angle in which participant pairs synchronized their rocking motion. The independent variables in the present study included the participants, the 4 conditions listed below, and the three trials per condition. The unit of analysis was for each pair of participants (either both children with ASD or TD children). See Table 1A (p. 45). The alpha level used to determine statistical significance was $p < 0.05$.

Measurement of each participant pair's ability to synchronize their rocking patterns were recorded during each of three trials for each of the 4 experimental conditions. The 4 conditions were as follows:

1. Forward Focus without Metronome (FFNM)
2. Forward Focus with Metronome (FFWM)
3. Direct Focus without Metronome (DFNM)
4. Direct Focus with Metronome (DFWM)

Experimental Conditions

Forward Focus No Metronome (FFNM)

The participants were seated (in correct testing form) in their rocking chairs positioned on their base marks. Participants were instructed to remain still until they heard the command “start rocking”. When they heard the “start rocking” command they were to begin rocking. Participants were also instructed to focus on a red “X” located at eye level on the wall directly in front of their chair. The command “stop rocking” was given at the end of 120 seconds at which time the participants stopped their rocking motion and remained still. This process was repeated for each of the three FF trials. The recorded data was then saved to an excel study file, and participants were given a rest period of 3 minutes.

Forward Focus with Metronome (FFWM)

The participants were seated (in correct testing form) in their rocking chairs which were positioned on their base marks. The participants were instructed to remain still until they heard the command “start rocking”. When they heard the “start rocking” command they began rocking while a metronome continuously “ticked”. Participants were also instructed to look at the red “X” located on the wall directly in front of their chair for each of the three 120 second trial durations of this condition. The command “stop rocking” was be given at the end of 120 seconds at which time the participants stopped their rocking motion and remained still. This process was repeated for each FF trial. The recorded data was saved to an excel study file, and participants were given a rest period of 3 minutes.

Direct Focus No Metronome (DFNM)

The participants were seated (in correct testing form) in their rocking chairs which were positioned on their base marks. The participants were instructed to remain still until they heard the command “start rocking”. When they heard the “start rocking” command they began rocking. Participants were also instructed to look at the red “X” now located on the inner armrest of their partner’s chair, for each of the three 120 second trial durations of this condition. Note the red “X” from the FF conditions has been taken down so it will not distract participants during the DF trials. The command “stop rocking” was given at the end of 120 seconds at which time the participants stopped their rocking motion and remained still. This process was repeated for each DF trial. The recorded data was saved to an excel study file, and participants were given a rest period of 3 minutes.

Direct Focus with Metronome (DFWM)

The participants were seated (in correct testing form) in their rocking chairs which were positioned on their base marks. The participants were instructed to remain still until they heard the command “start rocking”. When they heard the “start rocking” command they began rocking while a metronome continuously “ticked”. Participants were also instructed to look at the red “X” located on the inner armrest of their partner’s chair for each of the three 120 second trial durations of this condition. The command “stop rocking” was given at the end of 120 seconds at which time the participants stopped their rocking motion and remained still. This process was repeated for each DF trial. The recorded data was saved to an excel study file, and participants were given a rest period of 3 minutes.

Apparatus

Data Recordings

The data was initially collected on three-dimensional axis planes which represented the anterior-posterior (AP) (X value), the medial-lateral (ML) (Y value), and the vertical motion (VM) (Z value) of the sensors attached to the rocking chairs. While the study focused on the movement in the AP plane, the ML and VM coordinates were needed to determine the exact position of each sensor in relation to the tower transmitter at every point in time during each 2 minute trial. The saved data from each trial was imported into a Microsoft Excel spreadsheet for analysis.

Recording of Rocking Chair Position

The recorded data for this study was the first 90 seconds from each 120 second trial. This rationale was based on the following: 1) due to cycling rate variation throughout the trials, not all variable columns reached 7200 data points (i.e., the maximum amount of points to be recorded in 2 minutes; 60 cycles X 120 seconds) by the end of each 2 minute trial. 2) For some participants a large amount of chair travel occurred toward the end of random trials (i.e. the last 30 seconds), which could impact data points and rocking patterns in the AP plane.

The position of the sensors attached to each rocking chair recorded a data point every 0.01667 milliseconds during each 2 minute trial. Position was calculated using the Three-Dimensional Cartesian Coordinate Axis System. Letting P represent the position of a sensor for one point in time (i.e., every 0.01667 millisecond) per trial, is given by the following formula:

$$P = \sqrt{X^2 + Y^2 + Z^2}$$

Since all three values (i.e., X, Y, and Z) were already available it was only necessary to calculate the value of P for each of the 7200 sets of coordinates. Each calculation resulted in one point on the three-dimensional plane for each 0.01667 millisecond per trial (See Table 1a, Appendix E).

The phase angles for each rocking chair, and the points in time in which they moved during each 2 minute trial were calculated using the modified motion equation from the HKB model (Haken et al., 1985; Marsh et al., 2013). Due to the complexity of this calculation the process was broken down by algebraic order for solving an equation. Since the P value had already been determined, the following two equations were used to solve for phase angles. The following two equations from the HKB model represent chair/participant 1B and chair/participant 3A respectively.

The equation setup for the HKB model (Haken et al., 1985, p. 349) is as follows:

- $X_1 = r_1 \cos(\omega t + Ø_1)$
- $X_2 = r_2 \cos(\omega t + Ø_2)$

Values are defined by the following letters, numbers, and characters:

- X_1 = Point in time per chair/participant 1B defines the distance from the starting point, for rocking in each trial, to direction in space
- X_2 = Point in time per chair/participant 3A defines the distance from the starting point, for rocking in each trial, to direction in space
- r_1 = Peak amplitudes of chair/participant 1B
- r_1 = Peak amplitudes of chair/participant 3A
- $Ø_1$ = Phase angles of chair/participant 1B
- $Ø_2$ = Phase angles of chair/participant 3A
- ω = frequency
- t = time
- cos = cosine (or A(cos) which is the anti-cosine)

The calculated value cannot be greater than 1 or less than -1 as it will “error out” and not provide a value. For this reason the values computed from the HKB model and subsequent equations were calculated in radians. Finally, the absolute value of the difference between the relative phase angles of each participant in a pair was calculated for each time point (See Table 1b, Appendix E).

The trials that involved a metronome for the 2 minute duration were also calculated and graphed. The sine waves for the participants were also calculated using the HKB equation model. The metronome sine wave for each trial graph was calculated by multiplying each point of time (i.e., see calculation of the sensor position by point in time) by 3.14 (π) to create the “perfect” sine wave (See Table 1c, Appendix E).

- X = Points for "perfect" sine wave
- F = Order of data points during data collection
- # = The number of the row +1 in which the numbers for time are being calculated
- Equation setup is as follows: F * # / 60 (π) = X
- Example of the equation from column J, row 3:
- F * 2 / 60 = 0.016667 (3.14) = 0.052336

The metronome sine wave for each trial per pair of participants was individually centered on the graph based on the averaging of participant 1B and participant 3A's median calculations added to the "perfect" sine wave calculations (See Table 1b; Appendix E).

- X = average of participant medians
- J = Points of time in "perfect" sine wave
- K = Points of time in metronome sine wave which are trial specific

The equation setup is as follows:

- (1B median + 3A median) / 2 = X
- X + J = K

Once calculations for the data spreadsheet were complete, graphs based on the data were created. Graphs were created for Time Distance Comparisons which displayed sine waves for each of the participants in each pair per condition and trial. The Time Distance Comparisons illustrated the pairs rocking pattern likenesses and variations broken down by time for 90 seconds and their rocking chair sensor distance from the tower in centimeters (See Figures 1a & 1.1a, Appendix F). Graphs were also created for Time Distance Comparisons with Metronome for the conditions and trials that involved a metronome. These graphs were essentially the same as the Time Distance Comparisons with the addition of a metronome line (See Figures 1b &1.1b, Appendix F). From the sine wave graphs it was possible to calculate and graph the relative phase graphs which illustrated the synchronization between pairs per condition and trial by calculating the differences between the pair at every point in time and creating one sine wave representation of the two. The Relative Phase graphs illustrated the synchronization patterns by time for 90 seconds, in radians. *The stronger synchronization occurred the closer the sine waves got to zero* (See Figure 1c, Appendix F).

Calculations for Data Analysis

To further examine and analyze the data each calculated phase angle (i.e., calculation outputs were in radians) per point, per pair of participants, per trial was placed into "bins" (Marsh et al., 2013) or degree groups according to where they occurred on a 180 degree arc. The completed "bins" showed the amount of phase angle points that occurred within given degrees per 90 second trial; as by this point in the data analysis the trial time being analyzed had already been reduced to 90 seconds. Once the "bins" were set up, the statistical analyses were possible. The overall purpose of the bins was to divide data points into groups to assist in determining where the majority of synchronization between dyads occurred.

The following figure (2) represents the range of the relative phase angles created by the rocking chair sensors during the study trials. The initial resting position of the rocking chair sensors were 100 degrees. During testing the sensors generally traveled back and forth within the 5 and 120 degree range, with a few trials showing limited rocking up to 155 degrees. The sensors had the potential to travel within 0 to 180 degree range during all trials, however, the area of focus chosen for this study was the 5 to 30 degree range. Note the 5 degree bin holds all data points that fall within the 5.0 to 9.99 degree range, the 10 degree bins holds all data points that fall within the 10.0 to 14.9 degree range, this pattern continues for the 15, 20, 25, and 30 degree bins. The 180 degree arc was divided into 5 degree windows or "bins" (as they will be referred to in this study) to assist with determining statistical significance within the designated specific degree (i.e. 5, 10, 15, 20, 25, and 30 degree) areas.

Figure 2

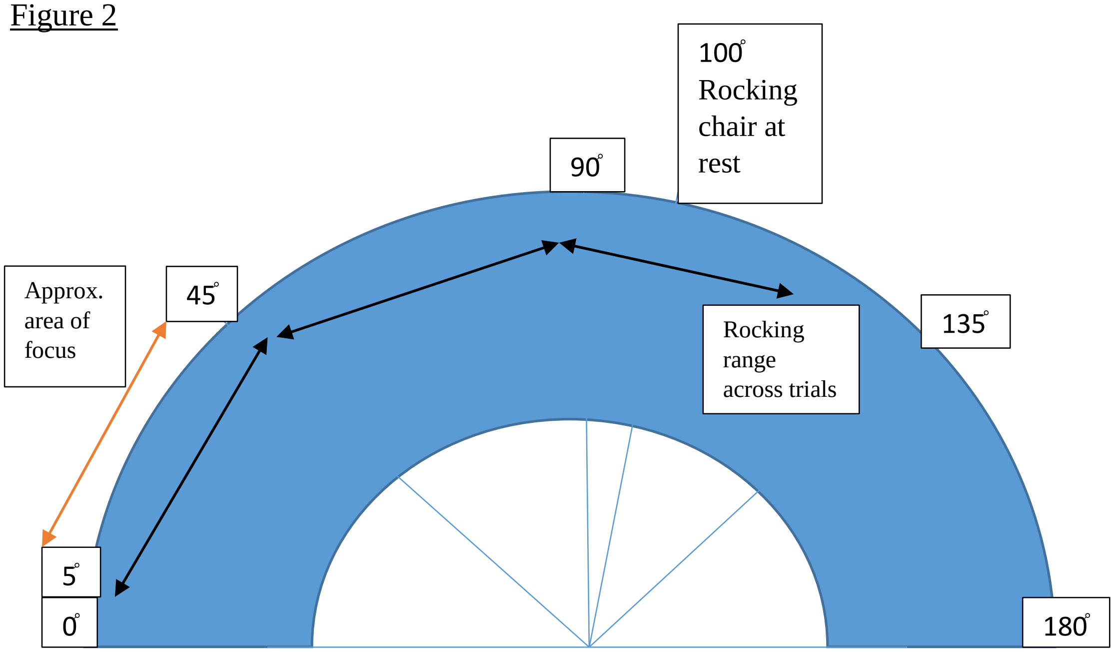


Illustration of rocking chair sensor range for phase angles shows resting degrees of the chair, rocking range across all trials, and the range of focus for the present study.

The statistical analyses conducted for this study fit Linear Mixed Effects (lme) model (Table 1) using the lme4 package in R version 3.1.1. The Linear Mixed Effects (lme) Model focused on comparing the ability of children to synchronize in each of the four conditions across the three trials. This 2 x 2 x 2 x 3 (i.e., Group = ASD/TD, Gaze = FF/DF, Pace = NM/WM, and Trials 1-3) model contained every possible combination of main, two-way, three-way and four-way effects allowing for a vast array of data analysis from many different perspectives. This was accomplished as the model created fixed effects that could be analyzed through random selection, using only the effects required for specific analysis. The lme model consisted of a between-subject factor (ASD or TD) and within-subjects factors (i.e., FF/DF, WM/NM, and trials) using the rocking synchronization relative phase measurement recorded every 0.01667 milliseconds as the dependent variable.

Table 1 Design of study: 2 x 2 x 2 x 3 Mixed Linear Effects Model

		Trial Order			
Groups	**Dyads**	**1, 2, 3**	**4, 5, 6**	**7, 8, 9**	**10, 11, 12**
Children with Autism (ASD)	AB	FFNM	FFWM	DFWM	DFNM
	CD	FFWM	FFNM	DFWM	DFNM
	EF	DFWM	DFNM	FFNM	FFWM
	GH	DFNM	DFWM	FFWM	FFNM
	IJ	FFWM	FFNM	DFNM	DFWM
Typically Developing Children (TD)	KL	DFNM	DFWM	FFNM	FFWM
	MN	DFWM	DFNM	FFWM	FFNM
	OP	FFNM	FFWM	DFNM	DFNM
	QR	DFNM	DFWM	FFNM	FFWM
	ST	FFWM	FFNM	DFWM	DFNM

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

This study assessed the ability of pairs of children with ASD to synchronize their rocking patterns, while external "third party" distractors were in play (i.e., visual and auditory). All participant pairs (i.e., ASD and TD) rocked for 1.5 minutes in each of three trials, in each of 4 conditions (i.e., FFWM, FFNM, DFWM, and DFNM). The data were analyzed using the Linear Mixed Effects (lme) Model, with relative phase as the dependent variable, recorded in radians**. It is important to note that the closer the value of relative phase radians is to zero, the greater the degree of synchrony.**

Recording and analyzing the relative phase angles, a 180 degree arc of all possible rocking ranges were divided into 5 separate degree windows ("bins"), which generated a total of 35 "bins". Most of the rocking activity took place below 120 degrees, with the motion of interest for this study, occurring between 5 and 30 degrees. Data analysis focused on the six bins that represented this range, (i.e., 5, 10, 15, 20, 25, and 30 degree bins).

The overall analysis showed a considerable overlap with respect to the three hypotheses central to the study. The results section reports first, the overall analyses of the main effects and interactions of interest, and this is presented in Table 2. The relative phase data for each of the 6 bins, for each of the three hypotheses, starting with the 5 degree bin, continuing to the last (30 degree) bin.

Table 2 - Group, Gaze, and Pace Means and Standard Deviations of Rocking Synchronization for pairs of ASD and TD Dyads

	ASD Means	ASD SDs	TD Means	TD SDs
Total Group (Summed across all conditions)	5.2	1.12	5.13	1.26
FF	5.2	1.07	5.09	1.03
DF	5.21	1.2	5.16	1.49
Gaze Total	5.2	1.12	5.13	1.26
Metronome	5.33	0.42	5.1	1.38
No Metronome	5.10	1.32	5.16	1.15
Pace Total	5.2	1.12	5.13	1.26

Figure 3 graphically illustrates Table 2. Children with ASD recorded higher mean scores for rocking synchronization than TD children in all areas with the exception of the no metronome condition. The SDs of children with ASD showed smaller ranges of variability in the FF and no metronome conditions.

Figure 3 – Graph of overall mean and SD for main effects.

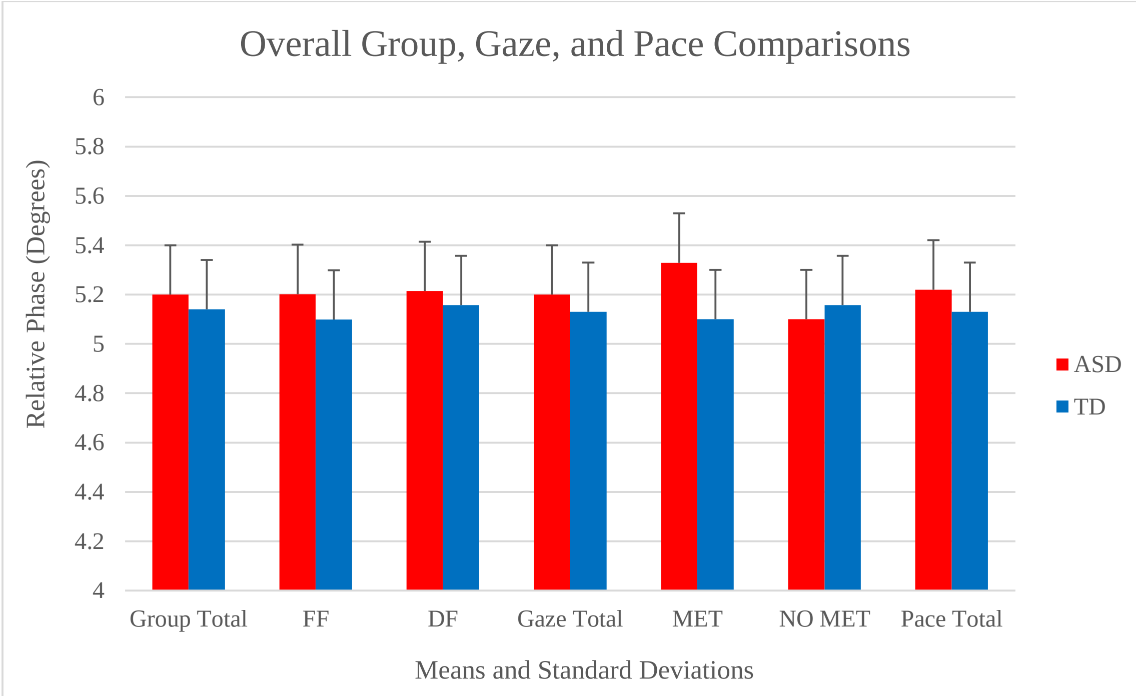


Table 3 illustrates that results across all 6 bins which share common statistically significant occurrences for the main effects and interactions. The main effect for Gaze was significant in 3 of the 6 bins (i.e., 5, 20, and 25). The Group x Gaze interaction was significant for the all, but the 10 degree bin; and Group x Pace interaction was significant for all bins except, the 10 and 25 degree bins. Reliable differences in rocking synchronization were present in both the 5 degree and 20 degree bins; only the Group x Gaze and Group x Pace interactions in the 15 degree bin; Group x Gaze interaction in the 25 degree bin; and all two-way interactions in the 30 degree bin. The mean Cohen's d values (effect size) for the main effects of Group, Gaze and Pace ranged from .186 to .213 for the 5 degree bin, and from .078 to .174 for the 20 degree bin.

Table 3 Chi-Square Statistics Testing for each main and two-way interaction effect

Main Effects	Bins					
	5	**10**	**15**	**20**	**25**	**30**
Group	** 46.41	0	0	** 105.61	* 7.88	0
Gaze	** 25.25	** 9.22	0	** 48.29	1.35	0
Pace	** 54.62	0	0	** 17.03	0	0
Trial	** 44.16	0	4.92	* 6.93	0	0
Group : Gaze	** 36.03	0	** 11.92	** 44.86	* 7.15	** 11.89
Group : Pace	** 50.85	0	** 9.68	** 48.45	0	** 10.38
Group : Trial	** 19.29	** 46.86	0	** 31.76	0	* 7.35
Gaze : Pace	** 51.43	0	0	** 40.18	0	** 15.47
Gaze : Trial	0	0	0	** 12.33	0	* 10.54
Pace : Trial	** 28.77	0	0	** 13.93	0	** 12.87

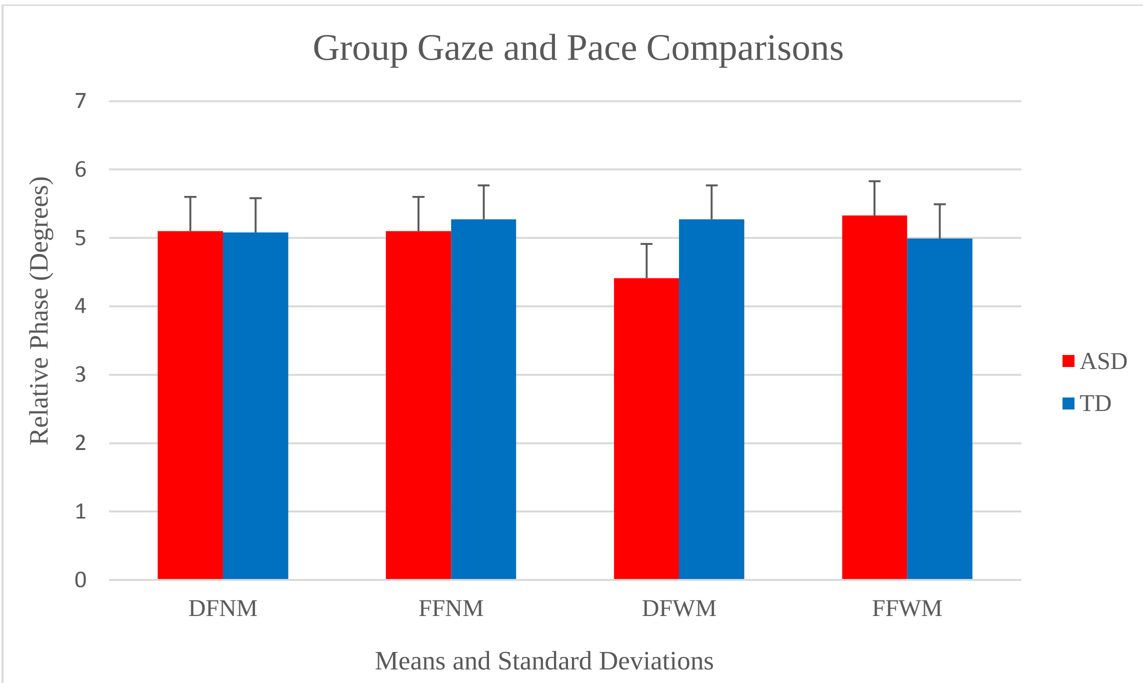
p. < 0.05 = *, p. < 0.01 = **

Figure 4 illustrates the means and SDs for Group, Gaze, and Pace conditions. The DFNM condition shows no difference between children with ASD and TD children. The DFWM condition illustrates children with ASD synchronizing better (lower mean score) than TD children.

The FF conditions illustrated in Figure 4 show children with ASD as having a lower mean than TD children in the no metronome condition. Children with ASD showed a higher mean compared to TD children in the FF paced condition. The SD for the FFNM shows a lower level of variability compared to the FFWM condition. The

FFWM condition illustrates higher variability for children with ASD compared to TD children.

Figure 4 - Graph of Group mean and SD Trial comparisons for Gaze and Pace



Results

Figure 5 A-D Illustrates relative phase graphs between the two groups, in the two Gaze conditions (FF and DF), and the two Pace conditions (Metronome and No metronome). The graphs are a sample representation of the most consistent performances between ASD and TD dyads.

Figure 5A illustrates the FFWM condition. The ASD sine wave shows no form of pattern, consistency, or “tightness” (i.e., closeness to zero) across the trial. The TD sine wave is also not “tight” to the zero point, but a slight pattern can be detected and the overall pattern is smoother showing better consistency for the TD dyad.

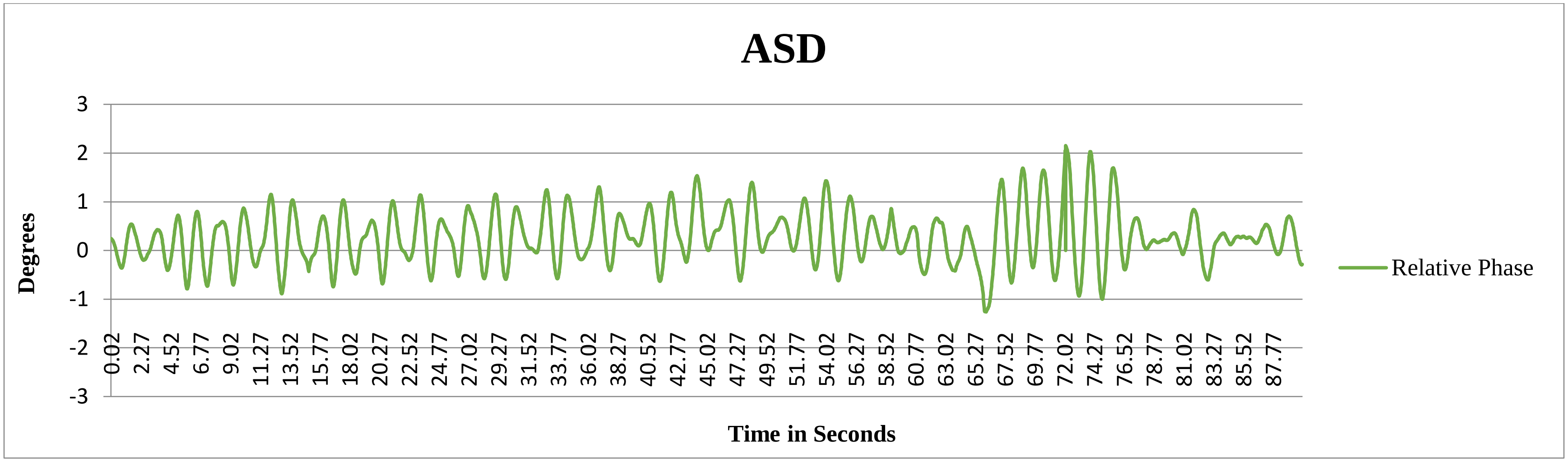
Figure 5B illustrates the FFNM condition. The ASD sine wave shows a limited pattern, that approaches closer to zero at random points, but is not consistent for any extended period. The TD sine wave is a more random pattern in the beginning of the trial, but mid-way in the trial appears most consistent and remains for approximately 25 seconds before they again move farther away from zero.

Figure 5C illustrates the DFNM condition. As shown in Figure 5C, the ASD sine wave shows a limited pattern that gets closer to zero at random points, but is not consistent for any extended period of time. The TD sine wave illustrates a random pattern throughout the trial, but the line gets closer to the zero point as the trial progresses, suggesting that the TD dyad synchronized their rocking to a greater degree, as they got closer to the end of the trial.

Figure 5D illustrates the DFWM condition. The ASD sine wave shows a limited pattern where the sine wave gets closer to zero at random points, but does not remain consistent for an extended period of time. The TD sine wave is clearly closer to the zero point across this trial. The TD sine wave is smooth at the beginning of the trial, about mid-way it becomes variable for a short period, then smooths out again toward the end of the trial, while the overall TD sine wave indicates greater synchronicity for the TD dyad.

Again as noted earlier, the closer to the zero point the sine waves fall, the higher the degree of rocking synchrony (interpersonal coordination) that will occur. From these representative samples of relative phase graphs, the TD dyads maintain a generally tighter relative phase coordination than the ASD dyads indicating that TD dyads synchronized their rocking more consistently than ASD dyads.

Figure 5A <u>Summary of ASD and TD comparison of Relative Phase for **FFWM**</u>



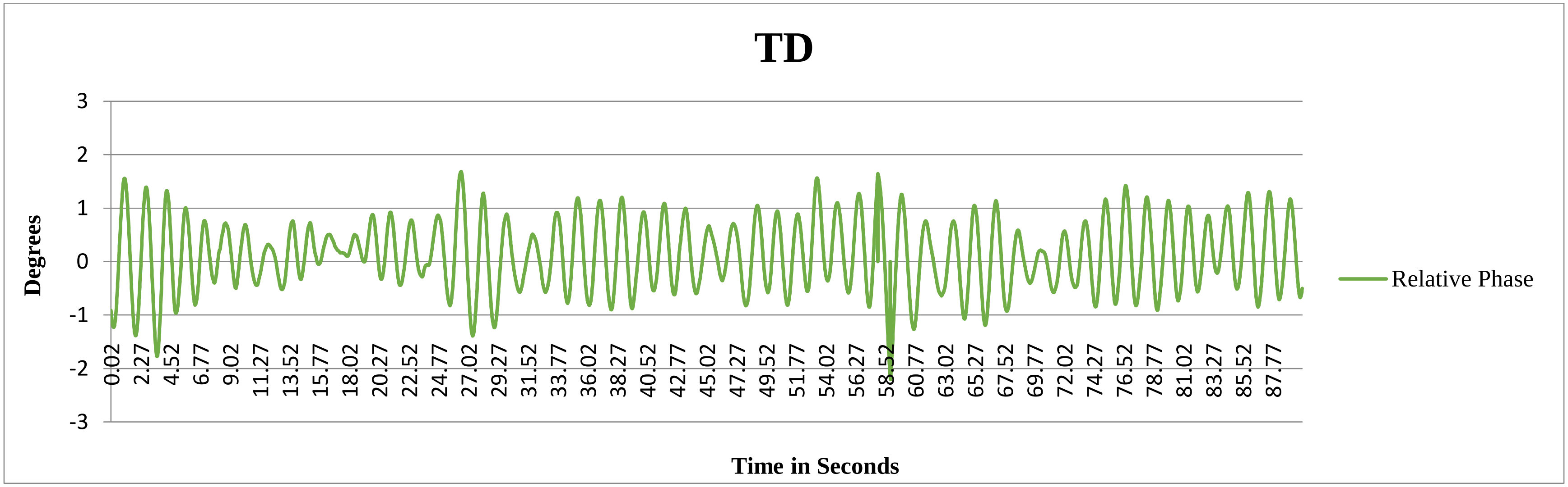
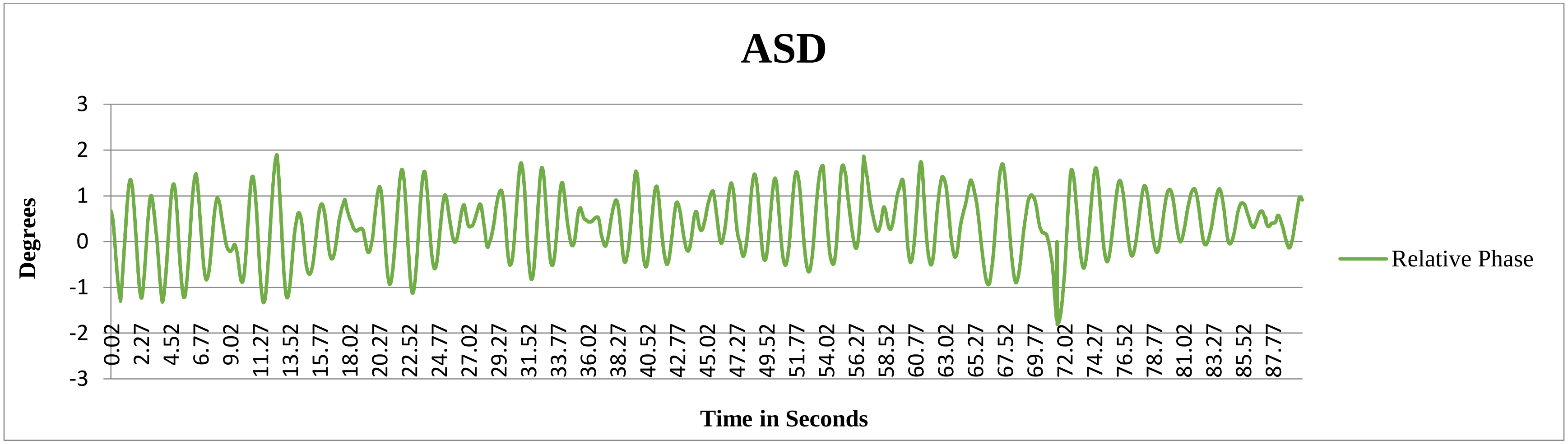


Figure 5B <u>Summary of ASD and TD comparison of Relative Phase for **FFNM**</u>



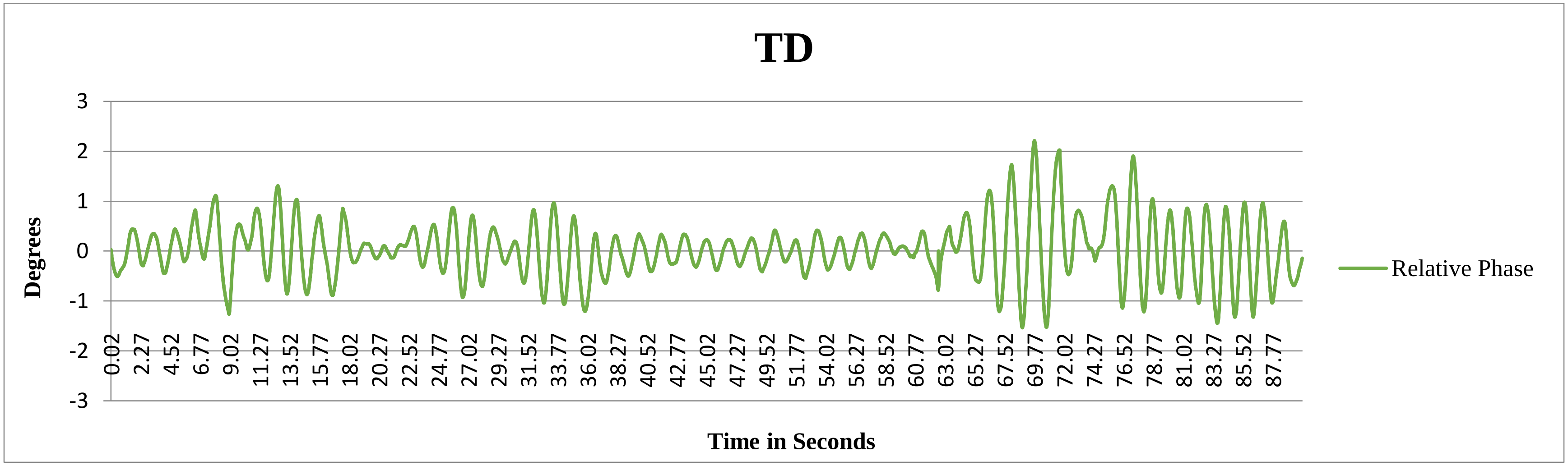
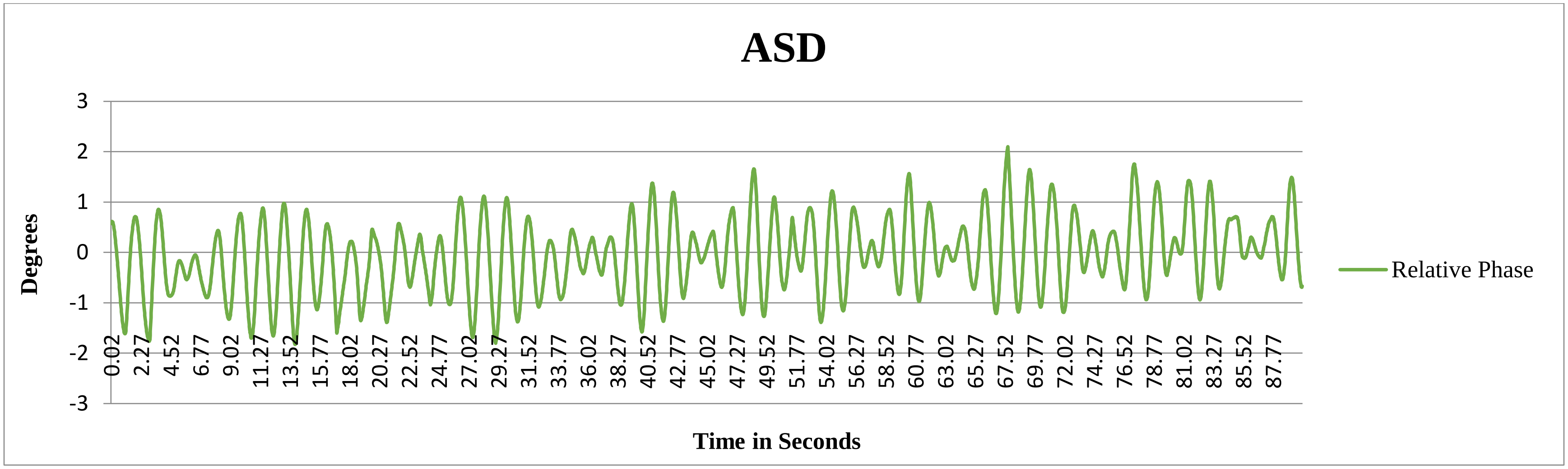


Figure 5C Summary of ASD and TD comparison of Relative Phase for **DFWM**



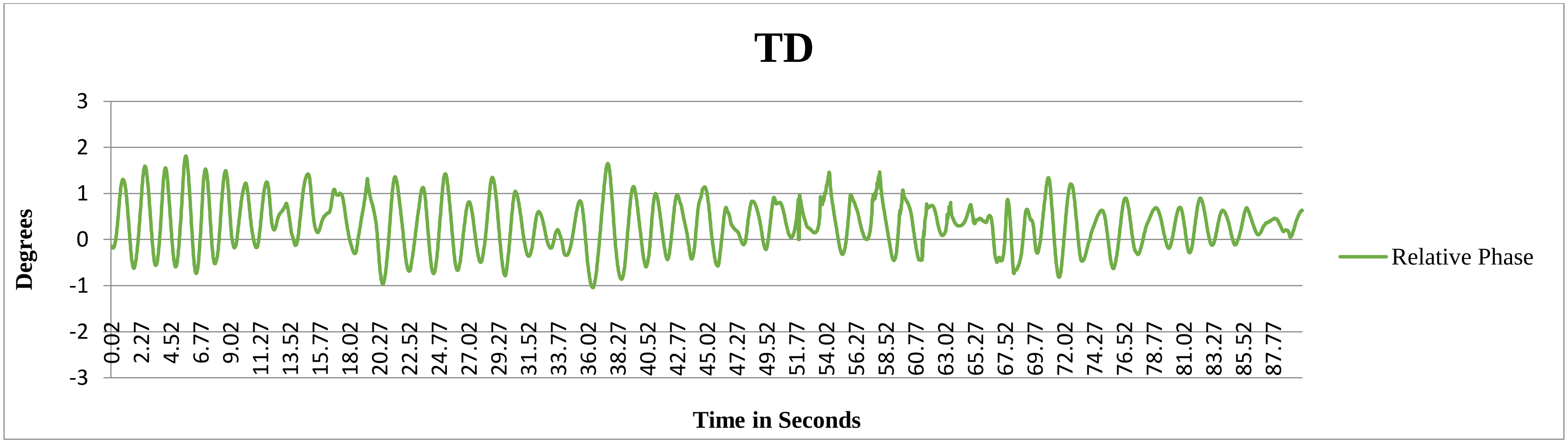
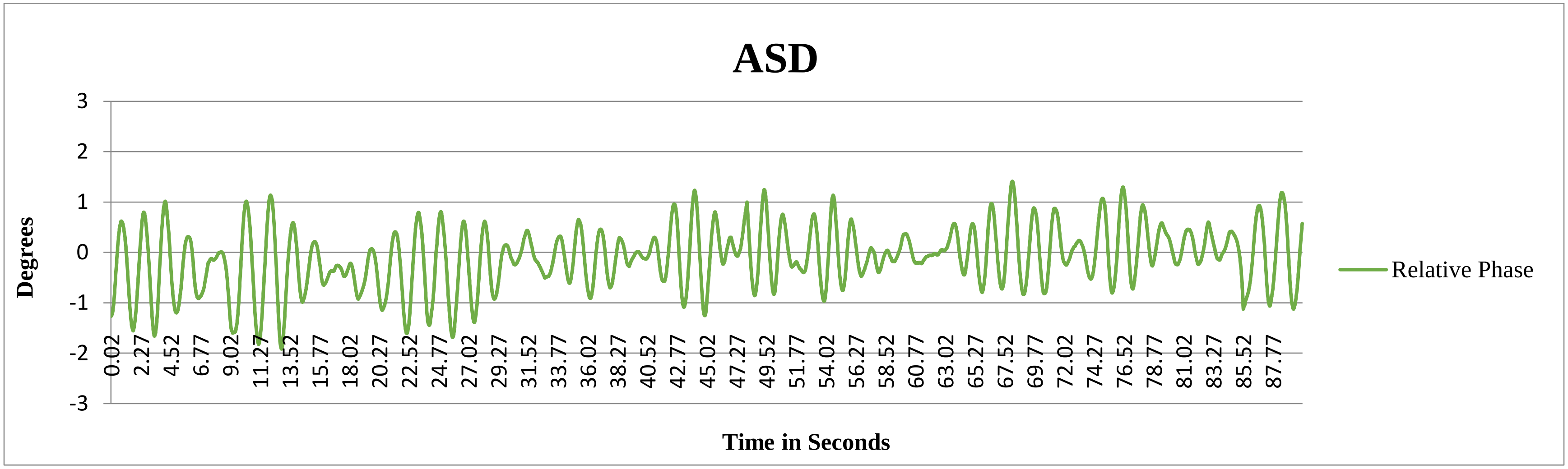
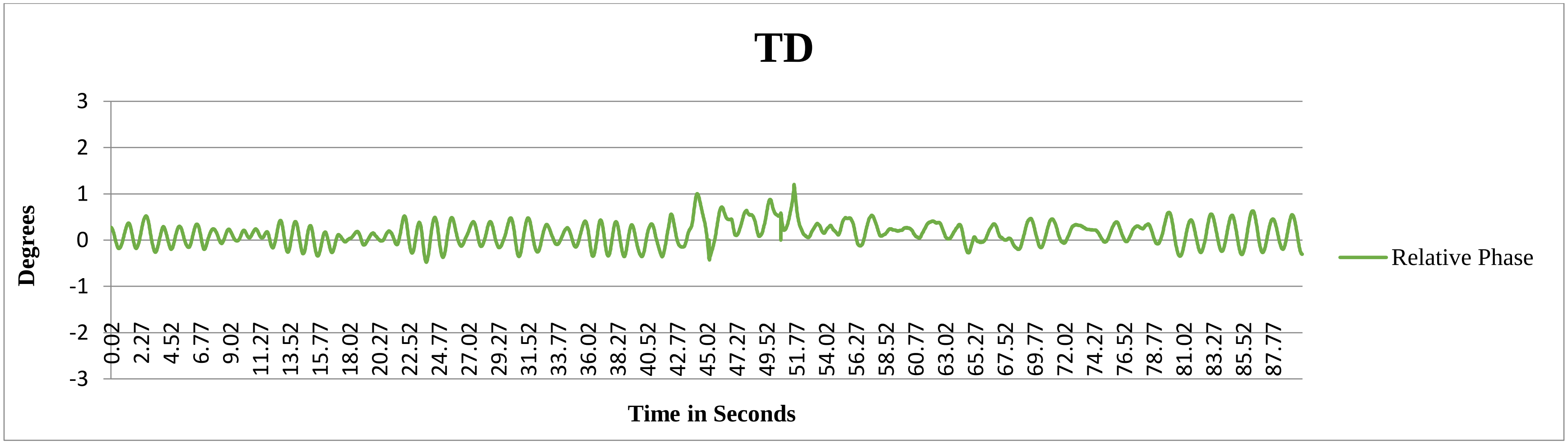


Figure 5D Summary of ASD and TD comparison of Relative Phase for **DFNM**



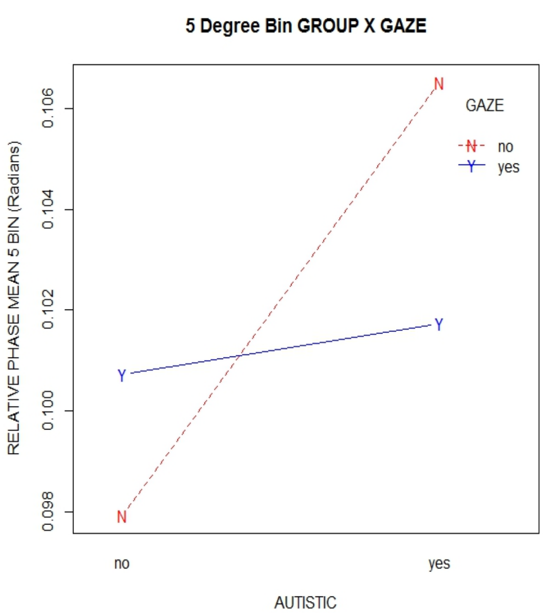


Group X Gaze Interaction:

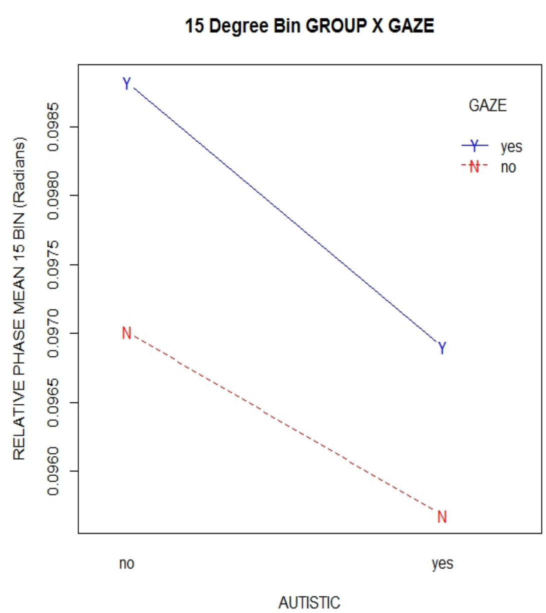
Figure 6 A-E, illustrates the Group x Gaze significant interactions for the 5, 15, 20, 25, and 30 degree bin. In the FF (Gaze = no) condition, TD children (ASD/No) were better able to synchronize their rocking producing lower relative phase values. In the DF (Gaze = yes) condition children with ASD were able to reliably synchronize their rocking better than TD in 2 of the 6 degree bins (i.e., 15, and 20 degree bins) and was almost equal in the 5 degree bin (Figure 6A). Overall the FF conditions recorded higher levels of group synchronizing (relative phase closer to zero) than the DF.

Figure 6 – Group x Gaze interactions for ASD and TD dyads for 5 degree (A), 15 degree (B), 20 degree (C), 25 degree (D), and 30 degree (E). Gaze/N = FF and Gaze/Y = DF.

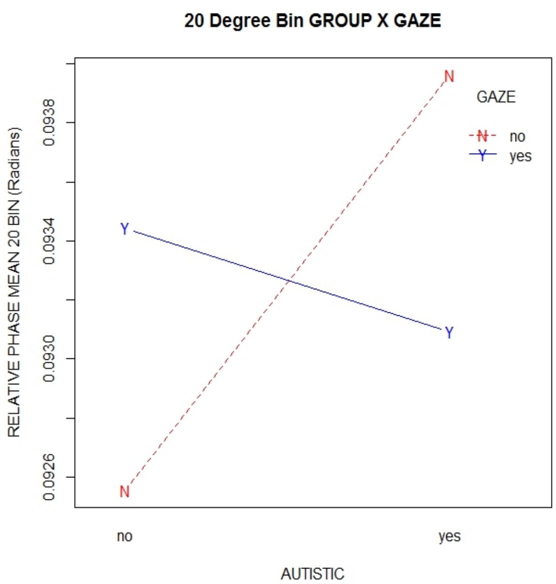
A. 5 degree



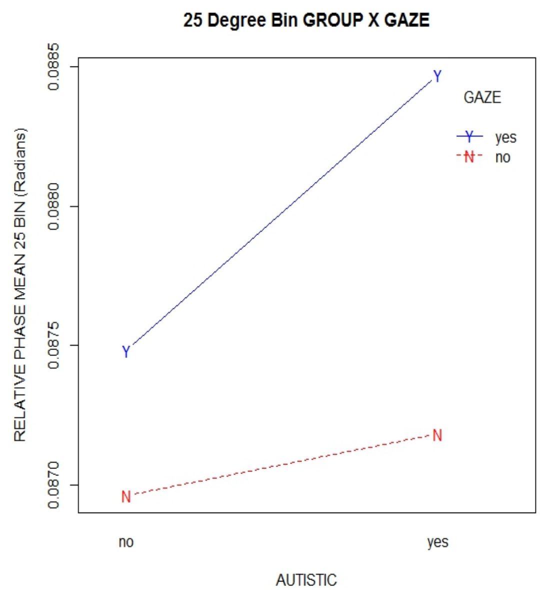
B. 15 degree



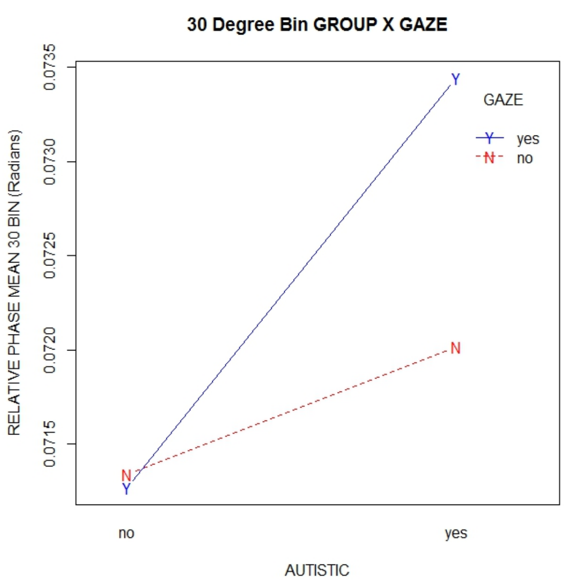
C. 20 degree



D. 25 degree



E. 30 degree

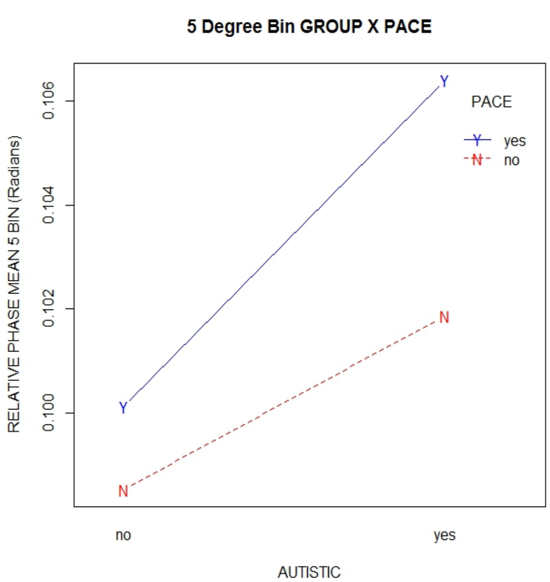


Group X Pace Interaction:

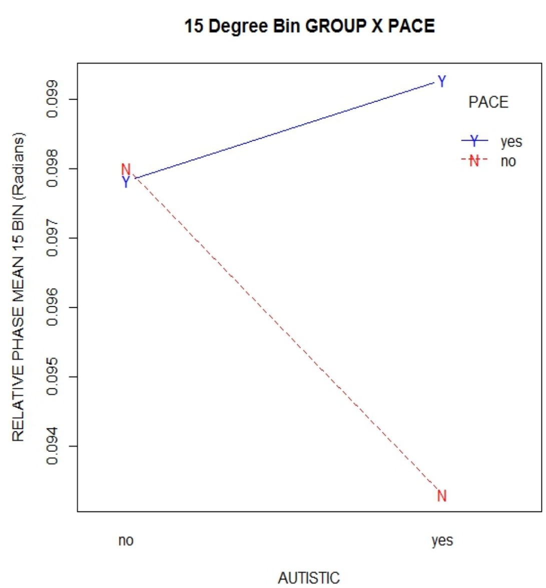
Figure 7 A-D, Group x Pace illustrates the significant interactions for the 5, 15, 20 and 30 degree bins, for the pace condition (metronome and no metronome). The no pace condition shows that children with ASD synchronized rocking better than TD children in bins 15, and 20, and worse in bins 5 and 30. In the paced condition the TD dyads synchronized their rocking to a significantly higher degree in all four bins (5, 15, 20, and 30).

Figure 7 – Group x Pace significant interactions for ASD and TD dyads, for the 5 degree (A), 15 degree (B), 20 degree (C), and 30 degree (D) interactions. Pace/N = no pace and Pace/Y = paced.

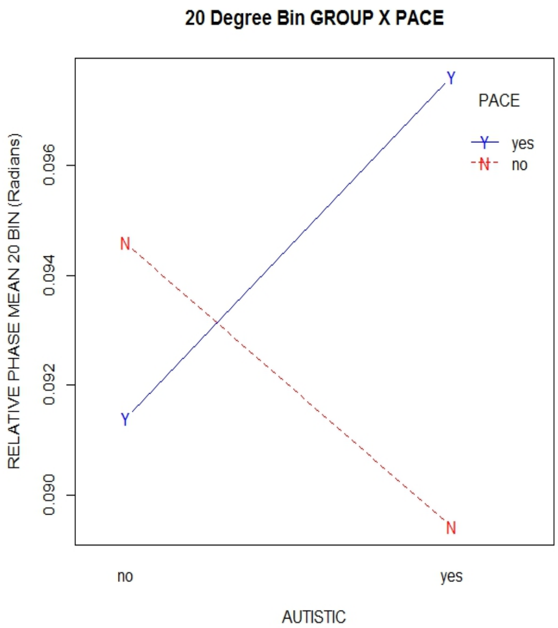
A. 5 degree



B. 15 degree



C. 20 degree



D. 30 degree

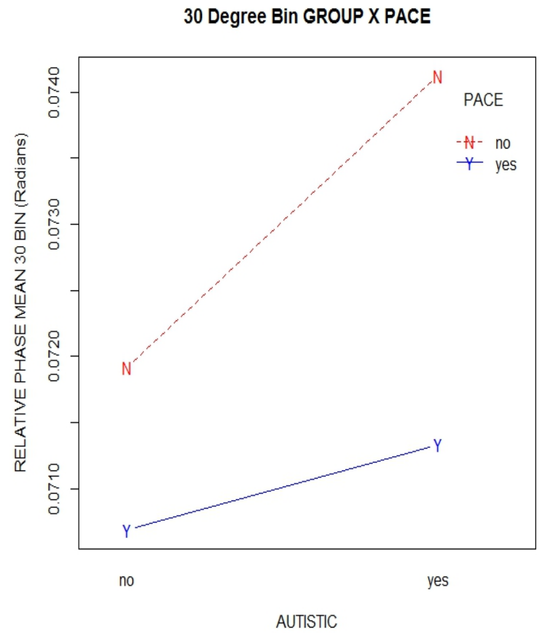
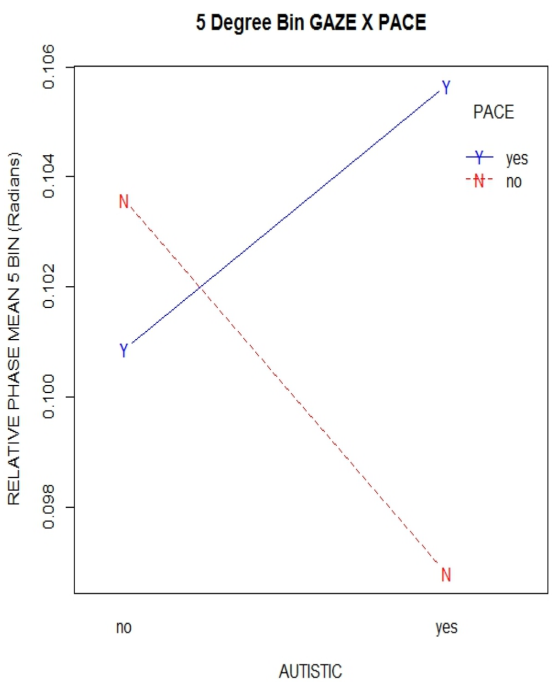


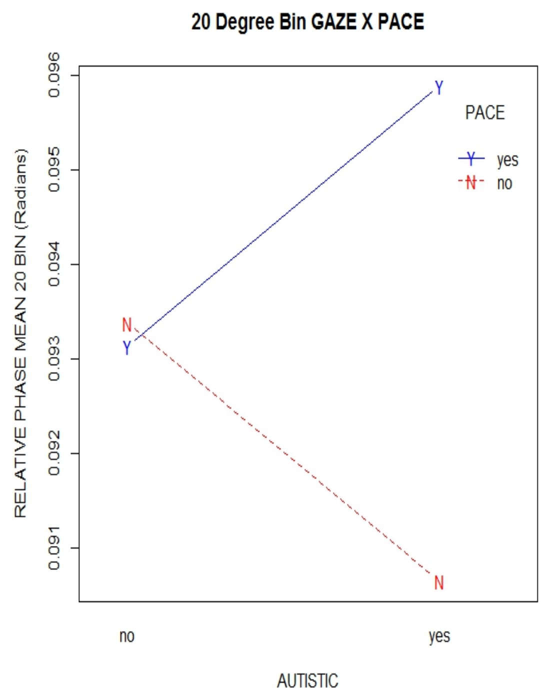
Figure 8 A-C, Gaze x Pace illustrates the significant interactions for the 5, 20, and 30 degree bins. Figure 8 A-C shows the DF condition synching better than the FF condition in all three bins, with the DFNM comprising two of the three bins (5 and 20 degree). Earlier discussion about Figure 6A-E, Group x Gaze for the DF condition showed that children with ASD reliably synchronized their rocking better than TD in 2 of the 6 degree bins (i.e., 15, and 20 degree bins) and were almost equal in the 5 degree bin (Figure 6A). Also, noted earlier for the Group x Pace (Figure 7A-D) significant interactions for the pace and no pace condition of which children with ASD synched better in two of the four no pace degree bins compared to TD, providing inconclusive results. This suggests more participant groups and trials may be needed to provide more clarity regarding ASD performances in paced and no paced conditions.

Figure 8 – Gaze x Pace significant interactions for ASD and TD dyads, in the 5 degree (A), 20 degree (B), and 30 degree (C) interactions. Gaze/N = FF and Gaze/Y = DF.

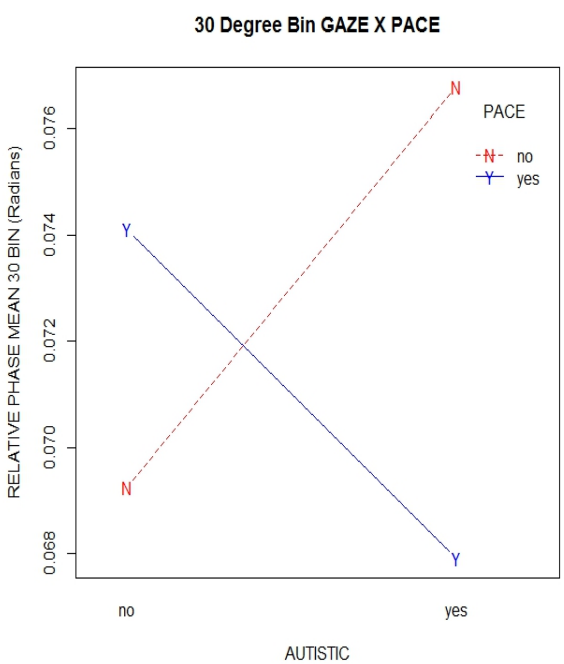
A. 5 degree

B. 20 degree





C. 30 degree



Hypothesis 1 predicted that the relative strength of the coordination would be stronger in the TD dyads compared to the ASD dyads. From Table 2 it can be seen that significant group differences were present for the 5, 20 and 25 degree bins. The values recorded for the relative phase appear quite small, but are nevertheless significantly different in a direction that supports hypothesis 1. The mean values (degrees) for each of the three significant degree bins (ASD vs TD) were as follows; 5 degree 5.96 vs 5.67; 20 degree 5.39 vs 5.33; 25 degree 5.04 vs 4.99.

Main effects of group:

"Some People rock" (Donnellan et al., 2013, p.1), although the rationale and motivation for their rocking movement can vary by individual. Iarocci and Dapretto (2006) noted that in some situations and environments a rocking response is dictated by the level and type of stimulus presented at any given moment. The stimulus may also be in the form of a sound or series of sounds that may influence or manipulate an individual's performance.

The group differences in rocking synchronization in degree bins 5, 20, and 25 (Table 2) are indicative of end points in the rocking cycle (i.e., forward and backward). The 5 degree bin represents the initiation of the forward rocking and the 20 and 25 degree bins represent endpoints of the forward motion and the start of the backward rocking. The 20 and 25 degree endpoints suggest that the pairs rocked more in synchrony going forward, their backward motion produced the degree of asynchrony that produced the group differences. The most obvious difference in backward endpoints is that one of the pair is rocking at a faster or slower velocity.

Hypothesis 1 predicted the opposite outcome: TD would synchronize better in DF conditions as children with ASD are neither accustomed to, nor comfortable with, face-to-face interactions (Böckler et al. 2011; Speer et al. 2007). Hypothesis 1 was supported by significant group effects in the 5, 20 and 25 degree bins, but not supported for significant group effects in the Group x Gaze interaction.

Hypothesis 1 also predicted that TD children would synchronize better in the no pace conditions as children with ASD are more apt to focus attention on a single stimuli as opposed to multiple stimuli which can cause distraction (Brock, Freuler, Baranek, Watson, Poe, and Sabatino, 2012; Grandin, 1992a, 1992b, 1992c). With only one task (rocking) and no metronome present to act as a distractor may potentially be the reason ASD children synchronized better in half of the no pace conditions. The same argument might be used to explain why ASD children were unable to synchronize as well as TD dyads in the paced conditions because of the presence of multiple stimuli. Hypothesis 1 was supported by significant group effects in the 5, 20 and 25 degree bins (See Table 3), and the overall Group x Pace interaction (See Figure 3).

Hypothesis 2 states that children with ASD will yield higher levels of coordinated rocking looking ahead (FF) than when maintaining eye contact with each other (DF). The results support this hypothesis.

Returning to Figure 6A-E above, the children with ASD were able to synchronize rocking at a higher level in the FF condition in the 15, 20, and 30 degree bins indicating that they tend to avoid direct eye contact in a variety of contexts. To date there are limited rocking studies involving children with ASD, and none that compare coordinated movement performance while rocking to variations in gaze direction, which is a key element of the present study. The few rocking studies that have been reported (Isenhower et al., 2009; Marsh et al., 2013; Richardson et al., 2007; Schmidt et al. 2008) comparing TD with ASD children the dyad groups comprised TD and ASD children together, unlike the present study which had dyads of like children with ASD and TD. The present study is a *first* that combines the elements of kinetic, communication, and visual components in a single experiment.

With respect to gaze direction Richardson et al. (2005) reported that "movement coordination can occur unconditionally where interaction is less physical and more psychological in nature" (p. 62). They also suggested that individuals tend to gravitate toward, and prefer to be around others who display similar movements and mannerisms to their own, much like the children with ASD in the present study. Marsh et al. (2009) stated that when two participants have like attitudes toward specific interests and "preexisting dispositional tendencies in society dimensions of personality" (P. 328), they are more apt to reinforce each other's beliefs. This can lead to a greater attraction for communicative behavior, (McGarva & Warner, 2003; Schmidt et al., 1994; Singer, Wolpert & Firth, 2004) including both kinetic and visual. Schmidt et al. (1994) reinforce these earlier statements adding that social coordination does not assure coordinated movement; rather, it is the intensity of complimentary social coordination that seems to produce an increase in coordination.

Support for the gaze hypothesis (2) (FF and DF) that ASD children synchronized better in the FF condition, is bolstered by earlier research that demonstrated that children with ASD were less sensitive to eye contact in social situations (Schulbach, Eickhoff, Cieslik, Kuzmanovic & Vogeley, 2011) and "tend to avoid eye contact" (Böckler et.al., 2011, p. 2). Children with ASD are averse to direct eye contact (i.e., a decreased inclination of sharing prolonged gaze) especially during a dynamic social interaction (Speer, Cook, McMahon & Clark, 2007). Children with ASD have been identified with utilizing lateral vision (the FF condition in the present study), to filter detailed spatial perceptual information, and high frequencies in movement perception (Mottron, Dawson, Soulièrs, Habert & Barack, 2006). These observations lend credence as to why the FF condition had higher synchronization rates compared to DF condition (See Figure 4). Temprado & Laurent (2004) found that peripheral focal conditions modulated the intensity of the visual component during spontaneous coordination, lending further support to the claim that the level of interpersonal coordination was influenced by the participant's attention to their partner's movement. While hypothesis 2 focused more on the visual aspect during conditions with and without a pacing stimulus (the metronome), Su (2014) suggests that "a rhythmic humanlike movement can serve as an effective visual beat that modulates auditory rhythm perception" (p. 120). Which leaves one to question if the synchronization was created either by visional perception, or if by the actual auditory beat of the metronome. Demos et al. (2011) concluded that the effect of visual and auditory stimulus *together* produced the highest level of spontaneous synchronization between partners, whereas vision only produced higher levels of spontaneous synchronization compared to an auditory stimulus. This question is further addressed in Hypothesis 3.

Hypothesis 3 states that for the ASD dyad trials the two pacing conditions FFWM and DFWM will generate higher synchronization rates than the FF and DF conditions absent the metronome. The results do not support this hypothesis.

Cummins (2008) study contradicts the findings (or lack thereof) of the present study suggesting that the paced conditions would produce higher synchronization levels than those without the metronome, stating that "rhythm will be viewed as an affordance for movement, allowing the coordination of action with a stimulus" (Cummins, 2008, p. 16). He also concluded that rhythm created by sound added to the potential for physical movement coordination which had the capability to organize the behavior of multiple independent parties, leading to social relationships. Auditory, influences tend to have a social bonding effect (Cummins, 2008; Demos et al., 2011). Demos et al. (2011) also added that participants were able to synchronize with their partners to a greater degree when auditory stimulus was involved suggesting that it made them feel more connected to their partners. However, auditory stimulus was not tested as an isolated factor (as in the present study), but was combined with visual stimulus in all of the previous studies. It is unclear if the pacing referenced by the previous studies was formed through visual attention to their partner's movement, thereby creating a coordinated relationship, or if the coordination was produced solely by an auditory stimulus.

For the present study support for the no metronome conditions that yielded higher synchronization rates, Roley, Mailloux, Miller-Kuhaneck & Glennon (2007) suggest the potential for children with ASD to experience sensory overload to both the amount and type of stimulus (i.e. visual and auditory) to which they were exposed to during the testing phase. Multiple stimuli can create perceptual processing problems bought on in part by a hypersensitivity to sound (Roley et al., 2007; Thompson, 2011). Hypersensitivity to sound, combined with an exaggerated focus (i.e. prolonged gazing at an "X") could also trigger over-reactivity, narrowing the child's focus to only a few key elements within their environment (Liss, Saulnier, Fein & Kinsbourne, 2006). Temple Grandin (1992a, 1992b, 1992c), the world renown doctor diagnosed with ASD as a child, states that she would become so preoccupied with watching repetitive movement that she would block out everything else around her such that she neither saw nor heard anything else other than the object on which she was fixated. "I did it because it shut out the noise that hurt my ears. No sound intruded my fixation. It was like being deaf." (Grandin, 1992a, T.V. interview).

While the metronome was included in the present study as a third party, the reality was that it potentially acted as a distractor to children with ASD, as suggested by the results. Batshaw, Pellegrino & Roizen (2007) concluded that when children with ASD are exposed to sounds or noise they may either react with indifference, mentally block out the noise aggravation, or cover their ears.

Summary Discussion

The overall goal of the present study was to determine if participants coordinated their rocking motion to that of their partner while influenced by either visual or auditory aspects of the experimental protocol. The present study may also reflect a comment by Wolff (1968) who suggested, "Whenever the motor patterns have the same form, the rates of performance (or rhythms) tend to be the same" (p. 478), indicating a stronger level of synchronization. This may account for the level of synchronization reported in the present study. It is possible that some dyads were more comfortable and in-tune with their partner during the testing session, thereby, creating a stronger potential for coordinated movement. Past research supports this notion suggesting that participants were more inclined to gravitate toward others who simulated or produced movements similar to their own (Bernieri, 1988; Charney, 1966; LaFrance, 1979). Richardson et al. (2007) adds that coupling strength and interpersonal coordination stability, which is necessary for rocking synchronization, was stronger when information about their partner's movement (i.e. visual and auditory) was available. A study by Thaut (1987) found that children with ASD responded to auditory stimuli to a greater degree than TD children. However, it is important to note that not all responses to auditory stimuli (or any stimuli) will result in a positive outcome, some auditory stimuli can cause stereotypical behavior to emerge in children with ASD (Buderath et al., 2009; Gillberg, 1989; Hughes, 1996; Hyman & Towbain, 2007; Thompson, 2008; Thompson, 2011). Marsh et al. (2006) stated that social synergy was created within dyads through a "coordinated perception-action system with their partner. A temporary synchronization of movement rhythms was created when one was pulled into the natural orbit of another's movement" (p. 2). Demos et al. (2011) suggested that participants demonstrate intermittent synchronicity when observing their partners movement. They further note that unidirectional influences (i.e., music or white noise) can create a competition of sorts for the participant's attention. The ability of participants to coordinate was reflected in their capacity to self-organize via dynamic perceptuo-motor processing (Kelso, 1984; Konvalinka, Vuust, Roepstorff & Firth, 2010; Large, 2000; Richardson et al., 2005).

There are a limited number of studies that offered direct comparison and influence to the present study. Chang et al. (2010) and Marsh et al. (2013) provided insight to the present study in the form of social coordination through movement tasks (i.e., postural sway in the Chang et al. study, and partner rocking in the Marsh et al. study) involving children with ASD and TD children.

Chang et al. (2010) revealed that both children with ASD and Td children "were able to functionally modulate postural sway to facilitate the performance of a task that required higher perceptual efforts" (p. 1536). This is comparable to the outcome of hypothesis 2 in which children with ASD synchronized rocking as well as TD children in the DFNM and better than TD children in the DFWM conditions. Both of these conditions (DFNM and DFWM) could be viewed as high effort conditions for a child with ASD due to the face-to-face rocking requirements with a partner whom they are not aquainted. Interestingly, in both studies, the overall results showed TD children performing better, yet, the differences between outcomes for ASD and TD children is minimal.

Marsh et al. (2013) were interested in "movement patterns the occurred under natural social interactions" (p.3) which is in essence spontaneous movement coordination which was examined in the present study. When examining natural social interactions one would expect that the bond between a parent and child would yield a strong connection. If this is correct, then rocking synchronization comparison between a parent and child should be stronger than the rocking synchronization of a child and a complete stranger. Marsh et al. (2013) revealed that TD children "spent more time rocking in-phase with their parent" (p.7) than children with ASD. However, their study did not mention if anti-phase was also considered as a form of synchronization leaving the question of whether children with ASD were able to synchronize rocking with their parent as well as TD children due to the following:

1. Lack of ability to coordinate movement.
2. Lack of interest in what their parent was doing due to their comfort level (i.e., interacting with a parent on a daily basis suggests a higher comfort level than being exposed to and having to interact with a complete stranger during testing).
3. Children with ASD were actually in anti-phase with their parents during the study, but anti-phase was not considered "in-synch" due to the parameters of the study.

These questions parallel the present study in regard to the levels of synchronization that occurred between the dyads of children with ASD. The children in the present study were not acquainted with their partner prior to testing which adds questions to spontaneous coordination and if there is a greater chance for coordination and synchronization when participants are familiar with each other? Definitely, something to consider for future studies.

The present study sought to expand on earlier studies and provide comparison data and insight on the ability of TD children and children diagnosed with ASD to synchronize their rocking patterns. The results of this study show that both ASD and TD dyads were able to coordinate their rocking synchronicity to some degree; but TD children, overall, were able to synchronize more consistently and to a greater degree compared to the children with ASD. An underlying rationale for the lower rocking performance of the children with ASD in the present study may not stem from their ability to rock (movement coordination). Both past and present studies suggest that children with ASD do demonstrate an ability to synchronize their rocking movement to some degree; but the problem may stem from their inability to relate to their partner (whether they are TD or ASD). In previous studies children with ASD were paired with TD children and TD parents (Isenhower et al., 2009; Marsh et al., 2013; Richardson et al. 2007); in the present study they were paired with another child with ASD; and in all studies they were compared to TD children, and in all studies the TD children performed at a higher level in coordination. The lower levels of socialization and inability of children with ASD to relate to others may be a key factor in their inability to consistently and spontaneously coordinate with others, whether it is expressed as movement or communication.

CHAPTER V

SUMMARY, CONCLUSIONS, IMPLICATIONS, AND LIMITATIONS

Summary of the Results

The present study provided data supporting the idea that children with ASD should be able to synchronize their rocking patterns with each other. In addition to coordinating with their partners, children with ASD revealed that they synchronized better in the FF conditions compared to DF conditions. This finding supported previous studies conducted on visual and environmental perceptions (Clark & Krych, 2004; Richardson & Dale, 2005) which also concluded that children with ASD preferred to avoid a face-to-face situation. This study also found that children with ASD were able to synchronize their rocking patterns to a higher degree in no paced (metronome not present, DF condition), compared to a pacer being present (metronome was present, FF condition). This suggested that children with ASD may coordinate to a greater extent in environments and social situations that offer visual information as opposed to auditory (i.e., solo stimulus) information on the individuals around them (Bahrick & Lickliter, 2004; Miles et al., 2009; Richardson et al., 2007).

The synchronized rocking capabilities and interpersonal coordination levels of children with ASD were compared to TD children. The results from the two comparisons revealed little difference between children with ASD and TD children in the 10, 15 and 25 degree bins, but showed greater difference between the two groups in the 5, 20 and 30 degree bins. To date studies on social coordination in children with ASD are limited.

Clearly, there is a need for more focus on this topic and the present study serves as a foundation from which to continue this process.

Conclusions

The present study investigated the interpersonal rocking coordination in children with ASD leading to the following conclusions:

1. Dyads of children with ASD synchronized rocking performance at higher levels (i.e., closer to zero relative phase) in the FF condition as compared to the DF condition. FF conditions revealed higher rocking synchronization in children with ASD when facing forward, than when facing their partner.
2. The pacing conditions revealed that children with ASD were able to better synchronize rocking at higher levels in the no pace DF condition.
3. During testing, the DF condition aided in the pairs ability to synchronize.
4. When compared to TD children, children with ASD were able to synchronize rocking patterns, but not at the same level or consistency. The overall differences between ASD and TD were minimal.
5. Further studies comparing the synchronized rocking capabilities and interpersonal coordination levels of children with ASD and TD children need to be conducted.

Implications

Identifying the relationships between dyads of children with the documented social behaviors of ASD children and their ability to synchronize their rocking patterns may lead to intervention techniques in educational settings. Examples of techniques utilized could be working with a partner during Physical Education to complete a movement task, or working as a group in a history class to put on a small play. These interventions may offer the ability to improve learning, movement, socialization skills, and offer a greater understanding in regard to the capabilities of children with ASD. There is also the possibility that by emphasizing to children with ASD the value of direct eye contact while interacting with others may increase their ability to not only synchronize their movements, but also socially coordinate with their peers. The Oullier et al. (2008) study suggests that as soon as two individuals exchange even basic visual information they are more likely to coordinate their movements.

This study may also serve as a gateway study that would allow school districts to better utilize staff while providing a social support system for children with ASD. For example, if a child with ASD is able coordinate his/her rocking movements with another child with ASD and movement is a basic form of communication, can it also be inferred that these same children will be able to synchronize their social skills with each other and communicate at a higher level? By placing children diagnosed with ASD into peer groups with one or two other children with ASD and one paraprofessional 1) the school district can better utilize the paraprofessionals within the schools, and 2) the children would have consistent social opportunity (other than their para and family members) with peers that they interact with on a regular basis who can relate to the social struggles that come with ASD. While not all children with ASD may be able to be placed into social peer groups, due to other limitations, it is possible those able to spontaneously coordinate their movements with other children with ASD may be able to participate in alternative learning groups.

Limitations of the Study

1. While participants were tested during a one time meeting to keep them from gaining knowledge of the study prior to testing, only having contact with the study participants one time for testing made it unclear to determine if they would perform the same way if tested again on another day.
2. The study was unable to recruit 10 male TD participants, if all male subjects were tested the outcome for synchronization could be different due to gender.
3. Participants were only able to participate in the study if they met the criteria, one of which was that they needed to be under 81 pounds due to the weight restrictions of the rocking chairs. There were interested parties that had to be denied the opportunity to test as they did not fit in the rocking chair.
4. Reluctance of parents with children diagnosed with ASD to allow their children to participant in the study limited the amount of children who took place in the study. Having more children would have added greater strength to the sample size.

5. The lack of previous studies on interpersonal coordination on dyads of children with ASD limited the amount of supporting studies for or against the findings in the present study.
6. Originally, the present study was to be conducted in the conjunction with University of Minnesota's Autism institute, approximately 9 months of meeting and planning with the Autism Institute staff took place with a defined testing date set to begin in June of 2013. Two weeks before testing was to begin the Autism Institute backed out of the study reasoning they did not have any participants that would meet the criteria for the study. This limited the time the researcher had to find other participants to take part in the study in order to meet deadlines for completing the testing, analysis, and write-up in a timely manner.

Recommendations for Future Studies

Knowing that the present study is one of very few studies involving dyads of children with ASD it is recommended that more studies on interpersonal coordination in various domains (i.e. in-phase vs. anti-phase; types of third party distractors, vision, auditory, both; etc.) be conducted. The more studies done the better conclusions can be drawn about what learning styles and social interactions/opportunities are best for individuals with ASD. Suggestions for future studies include the following:

1. Replicating the present study with the use of the SMI Eye Tracking Glasses as they are used to get a better insight of the user's attention, action, and perception. Since

children with ASD are reported to have difficulty in these areas the use of these glasses may help pin-point where their focus is directed during required tasks.

2. As stated earlier more studies utilizing dyads of children with ASD may lead to further understanding in how they relate to children who share similar traits and characteristics as compared to other children who are considered to be TD.
3. This study utilized the interested participants who signed up to take part, meaning that both male and female participants were tested as a group. Future studies may choose to replicate the present study testing male and female participants separately to identify possible gender differences in children with ASD.
4. Further, studies could also be conducted on socialization aspects of children with ASD. Currently, there are a number of studies labeling children with ASD as socially withdrawn and void of emotion (Bass & Mulick, 2007; Joseph, 2002; Macintosh & Dissanayake, 2006; Scattone, 2007; Snedden, 2010). However, there are also TD children who are socially withdrawn and show little to no emotion. Plus, with observation of children with ASD in the present study and personal exposure, there seems to be much to debate as to whether children with ASD should be stereotyped in this manner.

Further studies are warranted based on what we have learned and questions we have yet to ask, yet we demonstrate "the capacity to empathize with people who move differently, and have popularized many affirmations based on Thoreau's advice to those who 'march to or hear a different drummer'" (Amos, 2013, p. 1). The ability to become engaged in and share interests with children with ASD from their perception rather than ours may allow the TD individuals of society to become more synchronized with their rhythms of exploration and development (Amos, 2013; Stillman, 2009). More often than not children with ASD are raised believing there is something wrong with them and that they need to be fixed (Donnellan et al., 2013) while what may need to be changed is not the child themselves, but the way they are perceived.

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APPENDIX A

CONSENT FORM

Spontaneous Interpersonal Coordination in Children with Autism

We would like to invite your child to be a participant in a research study that examines interpersonal coordination in children. Your child was selected as a possible participant because we are looking for children 7-11 years old. We ask that you read this form and ask any questions you may have before giving consent for your child to be in this study.

This study is being conducted by: Dr. Michael G. Wade and Lisa J. (Gasior) Kappes, Doctoral student in the school of Kinesiology at the University of Minnesota-Twin Cities.

Background Information

In daily behavior, individuals often exhibit rhythmically coordinated movement patterns with other individuals around them. Children with ASD sometimes find social interactions (making friends/engaging in social settings). Challenging social behavior of this kind requires interpersonal coordination and this type of behavior for many children is essentially intuitive. The central aim of this study is to determine if children with ASD are able to engage in spontaneous interpersonal coordination that occurs while performing a specific motor activity (rocking in a rocking chair).

Procedures

If you agree to allow your child to participate, we would ask your child to sit in a rocking chair and rock back and forth for 60 seconds trials in six conditions. In the first two conditions we will have them rocking without a partner, one with a metronome helping to keep time, and one without a metronome. This will help determine a baseline rocking pattern for each participant. Next we will have participants rocking with a partner. In the four partner conditions participants will be rocking while looking directly at their partner (with and without metronome pacing), and rocking while looking straight ahead /not at their partner (with and without metronome pacing). Each participant's performance will also be videotaped in order to measure and review the level of coordination that occurs between two children during each trial. The videotapes will not allow the children to be identified via face recognition, thus retaining confidentiality.

Risks and Benefits of being in the Study

The study involves minimal risk. Rocking in a chair may pose minimal risk if they fall, but the rate at which the participant's rock is slow and the chairs have arm rests for the participants to hold on to for added support to help prevent them from falling out of the chair.

There are no direct benefits of participation, but an anticipated benefit of this research is the potential to provide further insight regarding interpersonal socialization abilities in children and possibly creating future therapeutic and educational intervention strategies.

Compensation

Participation in this study is voluntary with no compensation.

Confidentiality

The records of this study will be kept private. We will not include any information that will make it possible to identify any subject in a report we might publish. Research records and video recordings of testing sessions will be stored securely and only researchers will have access to them. Study data will be encrypted according to current University policy for protection of confidentiality. Video recordings will be kept for 6 months after the study is complete and then be erased.

Voluntary Nature of the Study

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free withdraw at any time without affecting those relationships.

Contacts and Questions

The researchers conducting this study are: Dr. Michael G. Wade and Lisa J. (Gasior) Kappes. You may ask any questions you have now. If you have questions later, you are encouraged to contact them at the University of Minnesota, 1-612-626-2094, **mwade@umn.edu** or gasio013@umn.edu.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), you are encouraged to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

You will be given a copy of this information to keep for your records.

Statement of Consent

I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

Signature: ____

Date: ________________

Signature of parent or guardian: _______________________________________

Date: ________________

(If minors are involved)

Signature of Investigator: ____

Date: ________________

APPENDIX B

ASSENT FORM

Spontaneous Social Coordination in Children with Autism

I am asking if you are willing to be part of my study, because I am trying to learn more about how children your age move together while rocking. I am asking you to be part of my study because you are 7-11 years old. If you agree to be in this study, I will ask you to rock in a rocking chair while looking at a red “X”. There will also be another child rocking in a chair next to you.

You can ask any questions that you have about this study. If you have a question later that you did not think of now, you can ask me during rest times, when you are not rocking.

Saying “yes” to participating in my study means that you have had this paper read to you, that you understand what it says, and are willing to be part of this study. Taking part in this study is up to you, and no one will be mad at you if you don’t participate in my study or if you change your mind later.

Name of participant: ____

Signature of person explaining the study: ____________________________________

Date: _________________________________

APPENDIX C

Condition Instructions for Participants

This script is to be used for all phases of this study.

Pre-testing Script

ACTION: Greet study participants as they enter the room.

SAY: “Thank you for being part of my study today (insert child(ren’s) name(s)).”

SAY: “Before we begin testing first I am going read you the Assent form which explains the study and what I will need you to do during each condition.”

ACTION: Read the Assent form to the participants.

SAY: “Do you agree to be part of this study?”

ACTION: Once the participants agree to be part of the study assign them each a chair.

SAY: “This will be your chair for the duration of the study.” And “I would like you to sit with both feet on the floor and your arms resting either on the armrests or in your lap.”

“There is no talking while we are actively rocking in our chairs”

SAY: “We have six conditions to do, each condition has three trials each, so that equals eighteen trials total.”

ACTION: Demonstrate proper form for sitting in the rocking chair. Follow preset order of conditions for pair of participants.

SAY: “For all conditions you will start rocking when I say “Start Rocking” and rock for two minutes. When it is time to stop rocking for this trial I will say “Stop Rocking” at that time you will stop rocking and can stand up and stretch out.”

Baseline with Metronome

SAY: “Remember for this condition you will start rocking when I say “Start Rocking” and rock for two minutes. When it is time to stop rocking for this trial I will say “Stop Rocking” at that time you will stop rocking and can stand up and stretch out.”

SAY: “These three trials will also have a metronome playing while you are rocking, this is what it sounds like.”

ACTION: Turn on metronome so they can hear it and know what they are listen for and hearing during the trial.

SAY: “We will do this trial three times, then we will move on to another condition.”

SAY: “Do you have any questions?”

ACTION: Answer any questions they may have.

SAY: “Are you ready to begin?”

ACTION: Turn on metronome.

SAY: “OK, Start rocking.”

ACTION: Start data collection for this condition/trial and continue for duration of two minutes.”

SAY: “Stop rocking.” And “It is OK to stand and stretch at this time.”

ACTION: Repeat for a total of three trials.

If this is the second Baseline condition for this study remember to remove the wall divider after the third trial.

Baseline No Metronome

SAY: “Remember for this condition you will start rocking when I say “Start Rocking” and rock for two minutes. When it is time to stop rocking for this trial I will say “Stop Rocking” at that time you will stop rocking and can stand up and stretch out.”

SAY: “There will be no metronome for these three trials.”

SAY: “We will do this trial three times, then we will move on to another condition.”

SAY: “Do you have any questions?”

ACTION: Answer any questions they may have.

SAY: “Are you ready to begin?”

SAY: “OK, Start rocking.”

ACTION: Start data collection for this condition/trial and continue for duration of two minutes.”

SAY: “Stop rocking.” And “It is OK to stand and stretch at this time.”

ACTION: Repeat for a total of three trials.

Forward Focus with Metronome

SAY: “Remember for this condition you will start rocking when I say “Start Rocking” and rock for two minutes. When it is time to stop rocking for this trial I will say “Stop Rocking” at that time you will stop rocking and can stand up and stretch out.”

SAY: “These three trials will also have a metronome playing while you are rocking.

SAY: “For these three trials we will be looking at the big red X on the wall directly in front of you for each two minute trial you are rocking for this condition.”

SAY: “I want you to try to look at the red X the whole time you are rocking.”

SAY: “We will do this trial three times, then we will move on to another condition.”

SAY: “Do you have any questions?”

ACTION: Answer any questions they may have.

SAY: “Are you ready to begin?”

ACTION: Turn on metronome.

SAY: “OK, Start rocking.”

ACTION: Start data collection for this condition/trial and continue for duration of two minutes.”

SAY: “Stop rocking.” And “It is OK to stand and stretch at this time.”

ACTION: Repeat for a total of three trials.

<u>Forward Focus No Metronome</u>

SAY: “Remember for this condition you will start rocking when I say “Start Rocking” and rock for two minutes. When it is time to stop rocking for this trial I will say “Stop Rocking” at that time you will stop rocking and can stand up and stretch out.”

SAY: “For these three trials we will be looking at the big red X on the wall directly in front of you for each two minute trial you are rocking for this condition.”

SAY: “I want you to try to look at the red X the whole time you are rocking.”

SAY: “There will be no metronome for these three trials.”

SAY: “We will do this trial three times, then we will move on to another condition.”

SAY: “Do you have any questions?”

ACTION: Answer any questions they may have.

SAY: “Are you ready to begin?”

SAY: “OK, Start rocking.”

ACTION: Start data collection for this condition/trial and continue for duration of two minutes."

SAY: "Stop rocking." And "It is OK to stand and stretch at this time."

ACTION: Repeat for a total of three trials.

Direct Focus with Metronome

SAY: "Remember for this condition you will start rocking when I say "Start Rocking" and rock for two minutes. When it is time to stop rocking for this trial I will say "Stop Rocking" at that time you will stop rocking and can stand up and stretch out."

SAY: "These three trials will also have a metronome playing while you are rocking.

SAY: "For these three trials we will be looking at the big red X on the armrest of your partner's chair for each two minute trial you are rocking for this condition."

SAY: "I want you to try to look at the red X the whole time you are rocking."

SAY: "We will do this trial three times, then we will move on to another condition."

SAY: "Do you have any questions?"

ACTION: Answer any questions they may have.

SAY: "Are you ready to begin?"

ACTION: Turn on metronome.

SAY: "OK, Start rocking."

ACTION: Start data collection for this condition/trial and continue for duration of two minutes."

SAY: "Stop rocking." And "It is OK to stand and stretch at this time."

ACTION: Repeat for a total of three trials.

Direct Focus No Metronome

SAY: “Remember for this condition you will start rocking when I say “Start Rocking” and rock for two minutes. When it is time to stop rocking for this trial I will say “Stop Rocking” at that time you will stop rocking and can stand up and stretch out.”

SAY: “There will be no metronome for these three trials.”

SAY: “For these three trials we will be looking at the big red X on the armrest of your partner’s chair for each two minute trial you are rocking for this condition.”

SAY: “I want you to try to look at the red X the whole time you are rocking.”

SAY: “We will do this trial three times, then we will move on to another condition.”

SAY: “Do you have any questions?”

ACTION: Answer any questions they may have.

SAY: “Are you ready to begin?”

SAY: “OK, Start rocking.”

ACTION: Start data collection for this condition/trial and continue for duration of two minutes.”

SAY: “Stop rocking.” And “It is OK to stand and stretch at this time.”

ACTION: Repeat for a total of three trials.

End of Study

SAY: “We have reached the end of our study. I would like to thank you for participating.”

ACTION: Participants are free to leave testing room.

APPENDIX D

Syncing of Polhemus/Flock of Birds Systems

The system's synchronization and set up process began first by checking that all power-supply cables were secured to the Polhemus (i.e. Bird unit) and "plugged" into an operational electrical outlet. A power cable was also attached to the host computer and "plugged" into an operational electrical outlet. Both the host computer and Bird unit were then powered "on". The Flock of Birds system (PiMgr 2.7.1) was opened on the screen of the host computer revealing the operating screen.

Scrolling across the tool bar of operations "View" is selected and opened. The options given that needed to be "checked" for use included: graphics pane (which displayed the motion of the sensors during rocking activity), text pane (which showed the numerical data points being collected and recorded during rocking activity), status pane (which showed time, recording status, and sensor status during system use), and status bar (which displayed start/stop function, pause function, and fast/slow functions during system use).

Next on the tool bar "Device" was selected, Tracker Configuration was highlighted and "clicked" which allowed for measurement unit selection, this study was collected in centimeters (CM). The connection type display was set at USB, single Bird unit, with a Baud rate of 9.600 (set standard for "Standalone" study). The position filter was set at medium (due to size of testing field) and sensors #1 and #3 were set to active status as these were the two sensor/receiver ports selected for this study. Also, under "Device", Toggle Connection was "checked" as this operation syncs the transmitter/sensors with the system. The screen will display system sync with the sensors by highlighting their markers on the left side of the screen and stating "tracker/sensor connection via USB" in the note section at the bottom of the screen.

"Motion" was highlighted next on the tool bar. First, "Single Frame Recording" was tested to determine and set the starting position of each chair. After viewing the data for chair location minor adjustments were made to chair position in relation to the 90 degree angles to get both chair orientations to each other and the tower/transmitter as close to perfect synchronization as possible in the AP, ML, and VC planes prior to testing (Table AA).

Table AA

Chair	X Value	Y Value	Z Value
#1	76.138	32.998	23.652
#3	74.899	-36.637	29.609

Before Chair Synchronization Adjustments

Chair	X Value	Y Value	Z Value
#1	74.249	36.238	29.130
#3	74.899	-36.637	29.609

After Chair Synchronization Adjustments

When chair adjustments were complete a test trial was run to be sure all equipment was working correctly, this was done by selecting “Motion”, highlighting and “clicking” Toggle Continuous. This action initiated data collection which was noted by the rapid scrolling of numbers on the text pane. Recording was initiated by “clicking” the red dot (start/stop button) on top of the left side of the screen. When recording was initiated the timer on the mid-right side of the screen started to keep track of data collection time and the continuous rapid scrolling on the text pane stopped as the system recorded the data faster than it could be displayed. At the end of the test trial the red dot was “clicked” to stop recording. A test was also run on saving the test data. Saving recorded data began by highlighting and “clicking” file, scrolling down to “Export Motion Recording” which opens the link to name and save the data in a predetermined study file.

APPENDIX E

Table 1a - Replicate of data spreadsheet depicting Columns A-L and the first ten rows of participant's 1B and 3A data points and calculations.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Chair #	X Value	Y Value	Z Value	SQRT	Pt. Order	Pt Time		Pt Time	Sine-wave	Metronome	
2	1	78.784	26.502	33.809	89.73474	1	0.016667		0	0	86.2	
3	1	78.787	26.502	33.797	89.73285	2	0.033333		0.016667	0.052336	86.252336	
4	1	78.792	26.489	33.804	89.73604	3	0.05		0.033333	0.1045285	86.304528	
5	1	78.794	26.498	33.791	89.73556	4	0.066667		0.05	0.1564345	86.356434	
6	1	78.789	26.518	33.786	89.73519	5	0.083333		0.066667	0.2079117	86.407912	
7	1	78.786	26.534	33.795	89.74068	6	0.1		0.083333	0.258819	86.458819	
8	1	78.75	26.619	33.832	89.74819	7	0.116667		0.1	0.309017	86.509017	
9	1	78.742	26.7	33.787	89.74828	8	0.133333		0.116667	0.3583679	86.558368	
10	1	78.771	26.632	33.788	89.7539	9	0.15		0.133333	0.4067366	86.606737	
11	1	78.782	26.55	33.815	89.74943	10	0.166667		0.15	0.4539905	86.65399	
12	Data Continued											
13	3	69.899	-37.44	35.503	86.88145	1	0.016667		119.35	-0.891007	85.308993	
14	3	69.886	-37.46	35.513	86.88413	2	0.033333		119.3667	-0.913545	85.286455	
15	3	69.9	-37.43	35.501	86.87885	3	0.05		119.3833	-0.93358	85.26642	
16	3	69.902	-37.43	35.498	86.87579	4	0.066667		119.4	-0.951057	85.248943	
17	3	69.885	-37.44	35.516	86.87636	5	0.083333		119.4167	-0.965926	85.234074	
18	3	69.896	-37.41	35.512	86.86936	6	0.1		119.4333	-0.978148	85.221852	
19	3	69.895	-37.40	35.511	86.86341	7	0.116667		119.45	-0.987688	85.212312	
20	3	69.881	-37.42	35.519	86.86532	8	0.133333		119.4667	-0.994522	85.205478	
21	3	69.864	-37.45	35.524	86.86533	9	0.15		119.4833	-0.99863	85.20137	
22	3	69.865	-37.43	35.53	86.86255	10	0.166667		119.5	-1	85.2	
23	Data Continued											

APPENDIX E

Table 1b - Replicate of data spreadsheet depicting Columns A, and M-R and the first ten rows of participant's 1B and 3A data points and calculations.

	A	B – L	M	N	O	P	Q	R
1	**Chair #**		**SQRT-Median**	**M2-Par Median**	**ACOS(N2)**	**O2-((1/60)*G2)**	**Diff. PT. of pair**	**ABS of Q**
2	1		4.119737649	0.343884612	1.219746	1.219467854	-0.284974691	0.284975
3	1		4.117851186	0.343727144	1.219913	1.219357767	-0.283595098	0.283595
4	1		4.121039588	0.343993288	1.21963	1.218796562	-0.286264457	0.286264
5	1		4.120556615	0.343952973	1.219673	1.218561719	-0.287605676	0.287606
6	1		4.120191764	0.343922518	1.219705	1.218316375	-0.287313522	0.287314
7	1		4.125676268	0.344380323	1.219218	1.217551007	-0.290964908	0.290965
8	1		4.133191542	0.345007641	1.218549	1.216604956	-0.294320678	0.294321
9	1		4.133280947	0.345015104	1.218541	1.216319227	-0.293464529	0.293465
10	1		4.138901358	0.345484254	1.218042	1.215541562	-0.293961221	0.293961
11	1		4.134430355	0.345111048	1.218439	1.215661449	-0.294817615	0.294818
12	**Data Cont.**							
13	3		0.146449953	0.066027932	1.50472	1.504442546		
14	3		0.14913198	0.067237142	1.503508	1.502952865		
15	3		0.143851541	0.06485642	1.505894	1.505061019		
16	3		0.140787812	0.063475118	1.507279	1.506167395		
17	3		0.141362706	0.063734313	1.507019	1.505629897		
18	3		0.134358977	0.060576635	1.510183	1.508515916		
19	3		0.128408579	0.057893859	1.51287	1.510925634		
20	3		0.13032189	0.058756488	1.512006	1.509783757		
21	3		0.130328964	0.058759677	1.512003	1.509502784		
22	3		0.127552167	0.05750774	1.513257	1.510479064		
23	**Data Cont.**							

APPENDIX E

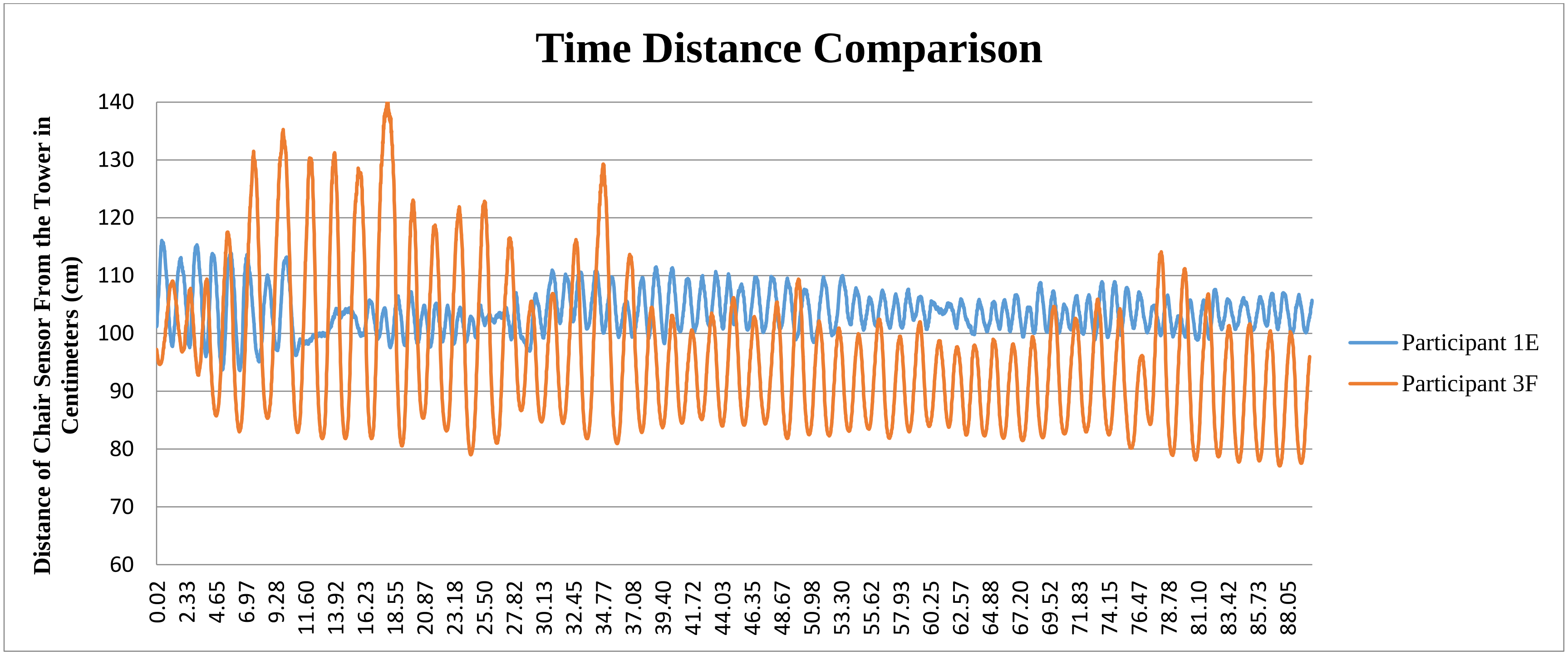
Table 1c

89.73474	**Participant 1B Starting Distance**
86.88145	**Participant 3A Starting Distance**
All Data Points	
73.63481	**Minimum value – furthest back chair rocked**
97.59574	**Maximum value – furthest forward chair rocked**
Participant 1B	
73.63481	**Minimum value – furthest back chair rocked**
97.59574	**Maximum value – furthest forward chair rocked**
Participant 3A	
84.51638	**Minimum value – furthest back chair rocked**
88.9526	**Maximum value – furthest forward chair rocked**
Participant 1B	
11.98047	**Participant 1B Peak Amplitude**
85.61528	**Participant 1B Median**
23.96093	**Participant 1B Peak to Peak Amplitude**
Participant 3A	
2.218111	**Participant 3A Peak Amplitude**
86.73449	**Participant 3A Median**
4.436221	**Participant 3A Peak to Peak Amplitude**

Further data collected and calculated that were needed to complete HKB model and subsequent equations so that data could be analyzed for statistical significance.

APPENDIX F

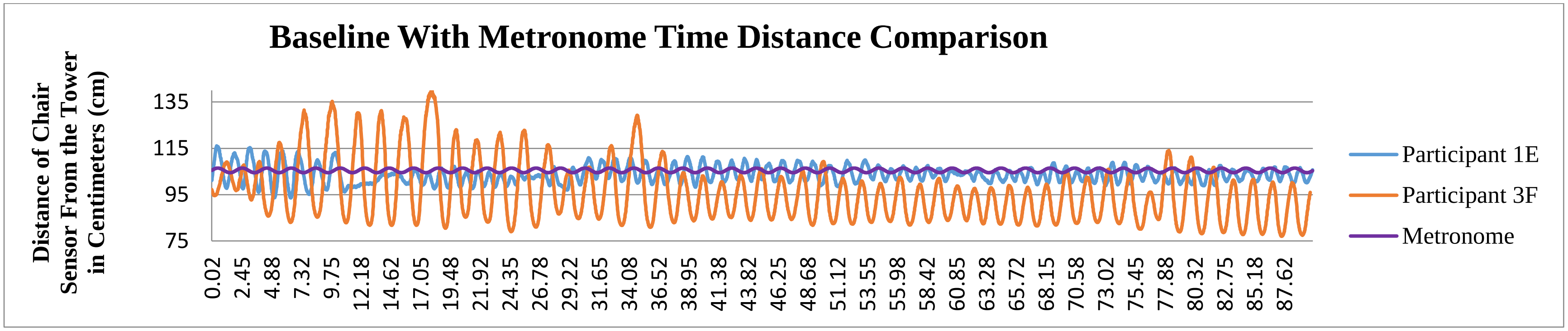
Figure 1a



Example depicting the comparisons between two participants (i.e., Participant E & Participant F) during a WM trial.

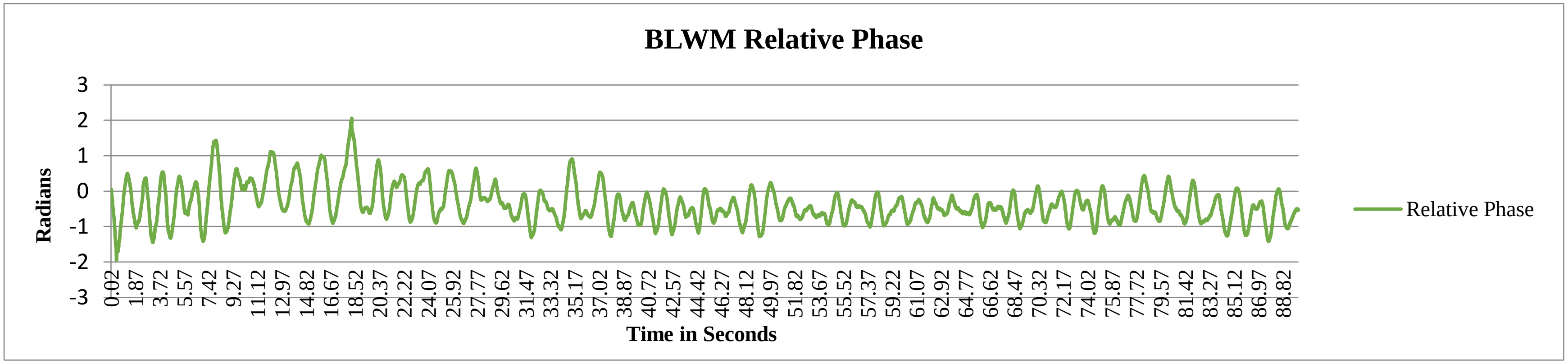
APPENDIX F

Figure 1b



Example depicting the comparisons between participants (i.e., Participant E & Participant F) and metronome sine wave.

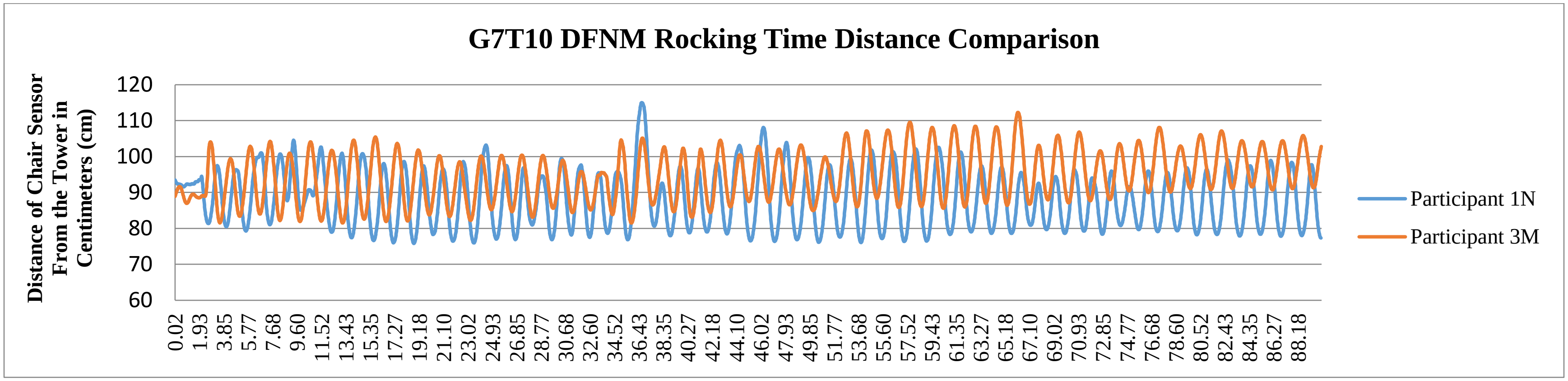
Figure 1c



Example depicting the phase angle differences between two participants (i.e., Participant E & Participant F) during a BLWM trial.

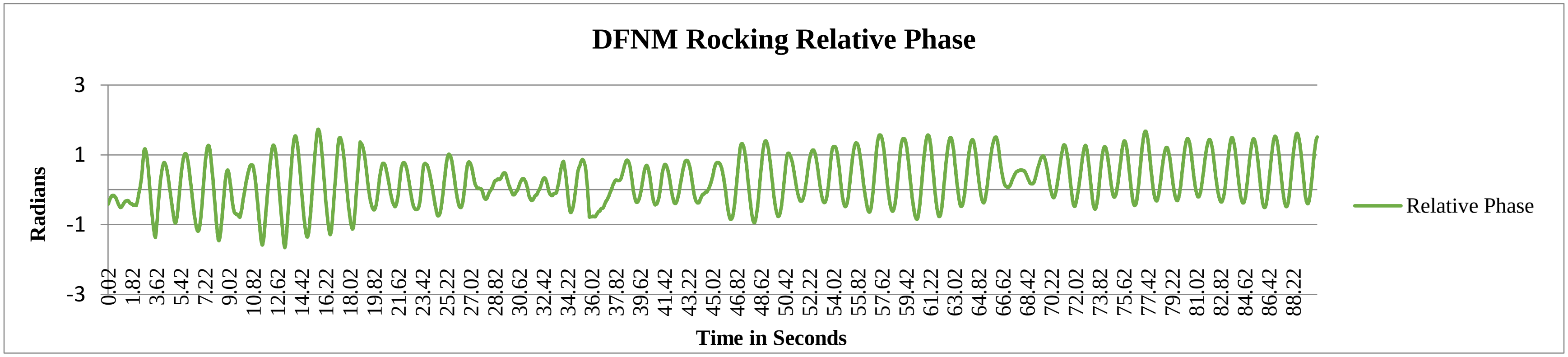
APPENDIX F

Figure 1.1a



Example depicting the comparisons between two participants (i.e., Participant N & Participant M) during a DFNM trial.

Figure 1.1b



Example depicting the phase angle differences between two participants (i.e., Participant N & Participant M) during a DFNM trial.

APPENDIX G

Table 2a

5 Degree Bin Cohen's d										
Trial	**SD**	**TD Mean**	**ASD Mean**	**Diagnosis Cohen's**	**Gaze FF Mean**	**Gaze DF Mean**	**Gaze Cohen's**	**Pace No Mean**	**Pace Yes Mean**	**Pace Cohen's**
1	0.033	0.107	0.106	0.041	0.103	0.110	0.206	0.104	0.109	0.150
2	0.030	0.096	0.104	0.262	0.103	0.097	0.227	0.102	0.099	0.102
3	0.024	0.094	0.102	0.336	0.100	0.097	0.131	0.095	0.102	0.306

Table 2b

10 Degree Bin Cohen's d										
Trial	**SD**	**TD Mean**	**ASD Mean**	**Diagnosis Cohen's**	**Gaze FF Mean**	**Gaze DF Mean**	**Gaze Cohen's**	**Pace No Mean**	**Pace Yes Mean**	**Pace Cohen's**
1	0.027	0.094	0.091	0.114	0.088	0.097	0.342	0.091	0.093	0.085
2	0.024	0.089	0.089	0.001	0.092	0.087	0.229	0.091	0.088	0.108
3	0.021	0.086	0.089	0.143	0.088	0.088	0.040	0.085	0.091	0.31

APPENDIX G

Table 2c

15 Degree Bin Cohen's d										
Trial	**SD**	**TD Mean**	**ASD Mean**	**Diagnosis Cohen's**	**Gaze FF Mean**	**Gaze DF Mean**	**Gaze Cohen's**	**Pace No Mean**	**Pace Yes Mean**	**Pace Cohen's**
1	0.027	0.100	0.099	0.052	0.096	0.103	0.272	0.099	0.101	0.094
2	0.021	0.099	0.097	0.109	0.100	0.096	0.156	0.098	0.097	0.043
3	0.021	0.094	0.093	0.057	0.093	0.094	0.019	0.090	0.097	0.341

Table 2d

20 Degree Bin Cohen's d										
Trial	**SD**	**TD Mean**	**ASD Mean**	**Diagnosis Cohen's**	**Gaze FF Mean**	**Gaze DF Mean**	**Gaze Cohen's**	**Pace No Mean**	**Pace Yes Mean**	**Pace Cohen's**
1	0.022	0.093	0.094	0.032	0.093	0.095	0.097	0.093	0.095	0.107
2	0.018	0.096	0.092	0.246	0.095	0.093	0.129	0.094	0.094	0.016
3	0.022	0.089	0.095	0.245	0.092	0.092	0.008	0.089	0.094	0.224

APPENDIX G

Table 2e

25 Degree Bin Cohen's d										
Trial	**SD**	**TD Mean**	**ASD Mean**	**Diagnosis Cohen's**	**Gaze FF Mean**	**Gaze DF Mean**	**Gaze Cohen's**	**Pace No Mean**	**Pace Yes Mean**	**Pace Cohen's**
1	0.017	0.085	0.088	0.165	0.086	0.087	0.017	0.085	0.087	0.116
2	0.015	0.089	0.085	0.283	0.087	0.087	0.046	0.088	0.086	0.101
3	0.020	0.087	0.091	0.164	0.088	0.090	0.086	0.088	0.090	0.085

Table 2f

30 Degree Bin Cohen's d										
Trial	**SD**	**TD Mean**	**ASD Mean**	**Diagnosis Cohen's**	**Gaze FF Mean**	**Gaze DF Mean**	**Gaze Cohen's**	**Pace No Mean**	**Pace Yes Mean**	**Pace Cohen's**
1	0.012	0.068	0.072	0.315	0.069	0.071	0.136	0.069	0.071	0.182
2	0.012	0.073	0.072	0.085	0.072	0.072	0.066	0.072	0.073	0.069
3	0.014	0.073	0.074	0.103	0.073	0.074	0.083	0.078	0.069	0.667

APPENDIX H

Participant Information								
ID	**Pair**	**Height**	**Weight**	**Age**	**Group**	**Gender**	**Vision**	**Grade**
A	1	60”	80lbs	11	ASD	Male	20/20	5th
B	1	55”	65lbs	11	ASD	Male	20/20	5th
C	2	56”	55lbs	9	ASD	Male	Corrected 20/20	3rd
D	2	50”	80lbs	10	ASD	Male	20/20	4th
E	3	50”	65lbs	7	ASD	Male	20/20	1st
F	3	47”	80lbs	7	ASD	Male	20/20	1st
G	4	47”	40lbs	7	ASD	Male	20/20	1st
H	4	44”	70lbs	7	ASD	Male	20/20	1st
I	5	50”	50lbs	8	ASD	Male	20/20	2nd
J	5	53”	60lbs	7	ASD	Male	20/20	1st
K	6	49”	53lbs	8	TD	Male	20/20	2nd
L	6	49”	50lbs	9	TD	Male	20/20	3rd
M	7	48”	55lbs	9	TD	Male	20/20	3rd
N	7	48”	50lbs	9	TD	Female	20/20	3rd
O	8	51”	51lbs	7	TD	Male	20/20	1st
P	8	51.5”	63lbs	8	TD	Female	20/20	2nd
Q	9	53.5”	65lbs	9	TD	Female	20/20	3rd
R	9	50.5”	64.5lbs	8	TD	Male	20/20	2nd
S	10	50.5”	70lbs	8	TD	Female	20/20	2nd
T	10	48”	72lbs	7	TD	Female	20/20	1st

APPENDIX I

Table 4a

EFFECT 5 Degree Bin	**DF**	χ^2	***p* value**
Group	1	46.409	9.596e-12
Gaze	1	25.254	5.026e-07
Pace	1	54.619	1.463e-13
Trial	2	44.156	2.581e-10
Group : Gaze	1	36.025	1.948e-09
Group : Pace	1	50.853	9.954e-13
Group : Trial	2	19.287	6.486e-05
Gaze : Pace	1	51.426	7.433e-13
Gaze : Trial	2	0	1
Pace : Trial	2	28.774	5.648e-07
Group : Gaze : Pace	1	23.198	1.461e-06
Group : Gaze : Trial	2	19.416	6.08e-05
Group : Pace : Trial	2	0	1
Gaze : Pace : Trial	2	0	1
Group : Gaze : Pace : Trial	2	42.119	7.144e-10

Sync5 at 90 seconds chart for statistical significance

APPENDIX I

Table 4b

EFFECT 10 Degree Bin	DF	χ^2	*p* value
Group	1	0	1
Gaze	1	9.2244	0.002388
Pace	1	0	1
Trial	2	0	1
Group : Gaze	1	0	1
Group : Pace	1	0	1
Group : Trial	2	46.857	6.684e-11
Gaze : Pace	1	0	1
Gaze : Trial	2	0	1
Pace : Trial	2	0	1
Group : Gaze : Pace	1	0	1
Group : Gaze : Trial	2	3.7216	0.1556
Group : Pace : Trial	2	0	1
Gaze : Pace : Trial	2	0	1
Group : Gaze : Pace : Trial	2	0	1

10 Degree Bin Synchronization at 90 seconds chart for statistical significance

APPENDIX I

Table 4c

EFFECT 15 Degree Bin	DF	χ^2	*p* value
Group	1	0	1
Gaze	1	0	1
Pace	1	0	1
Trial	2	4.9197	0.08545
Group : Gaze	1	11.921	0.0005552
Group : Pace	1	9.6842	0.001859
Group : Trial	2	0	1
Gaze : Pace	1	0	1
Gaze : Trial	2	0	1
Pace : Trial	2	0	1
Group : Gaze : Pace	1	0	1
Group : Gaze : Trial	2	0	1
Group : Pace : Trial	2	11.676	0.002915
Gaze : Pace : Trial	2	0	1
Group : Gaze : Pace : Trial	2	0	1

Sync15 at 90 seconds chart for statistical significance

APPENDIX I

Table 4d

EFFECT 20 Degree Bin	DF	χ^2	*p* value
Group	1	105.61	< 2.2e-16
Gaze	1	48.292	3.673e-12
Pace	1	17.027	3.684e-05
Trial	2	6.9312	0.03125
Group : Gaze	1	44.856	2.121e-11
Group : Pace	1	48.486	3.327e-12
Group : Trial	2	31.762	1.268e-07
Gaze : Pace	1	40.178	2.319e-10
Gaze : Trial	2	12.55	0.001883
Pace : Trial	2	13.931	0.0009441
Group : Gaze : Pace	1	51.869	5.933e-13
Group : Gaze : Trial	2	23.169	9.308e-06
Group : Pace : Trial	2	31.045	1.814e-07
Gaze : Pace : Trial	2	113.46	< 2.2e-16
Group : Gaze : Pace : Trial	2	30.219	2.741e-07

Sync20 at 90 seconds chart for statistical significance

APPENDIX I

Table 4e

EFFECT 25 Degree Bin	**DF**	χ^2	***p* value**
Group	1	7.8755	0.005011
Gaze	1	1.3514	0.245
Pace	1	0	1
Trial	2	0	1
Group : Gaze	1	7.1511	0.007492
Group : Pace	1	1.5482	0.2134
Group : Trial	2	0	1
Gaze : Pace	1	0	1
Gaze : Trial	2	0	1
Pace : Trial	2	0	1
Group : Gaze : Pace	1	0.8482	0.3571
Group : Gaze : Trial	2	0	1
Group : Pace : Trial	2	0	1
Gaze : Pace : Trial	2	7.2144	0.02713
Group : Gaze : Pace : Trial	2	0	1

Sync25 at 90 seconds chart for statistical significance

APPENDIX I

Table 4f

EFFECT 30 Degree Bin	DF	χ^2	*p* value
Group	1	0	1
Gaze	1	0	1
Pace	1	0	1
Trial	2	0	1
Group : Gaze	1	11.894	0.0005632
Group : Pace	1	10.375	0.001277
Group : Trial	2	7.3479	0.02538
Gaze : Pace	1	15.465	8.405e-05
Gaze : Trial	2	10.535	0.005157
Pace : Trial	2	12.868	0.001606
Group : Gaze : Pace	1	16.92	3.898e-05
Group : Gaze : Trial	2	15.935	0.0003465
Group : Pace : Trial	2	0	1
Gaze : Pace : Trial	2	0	1
Group : Gaze : Pace : Trial	2	1.5817	0.4535

Sync30 at 90 seconds chart for statistical significance